Availability and Efficacy of Ballast Water Treatment Technology: Background and Issue Paper

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Disclaimer:

This paper has been written to provide background information for EPA's Science Advisory Board in their evaluation of the technological availability of ballast water treatment systems. It has been drafted by EPA and USCG staff to assist the SAB board in its review. The contents of this paper do not necessarily reflect the views of the U.S. Environmental Protection Agency or the United States Coast Guard.

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On the Cover - the Port of Baltimore. *Photo taken by Ryan Albert.*

1. Introduction

Ballast water discharges have historically been a major source of nonindigenous species introductions to marine, estuarine, and freshwater ecosystems in the United States. Aquatic organisms may be discharged when the vessel discharges ballast tanks that contains such species, or when the vessel adds ballast water to tanks that contain such organisms in the residual water or sediment in the tank, and later discharges that mixture. When such organisms in ballast tanks are transported between waterbodies and discharged, the organisms may have the potential to establish viable new populations of species in waterbodies to which they are not native. Potentially, this introduction of non-native aquatic nuisance species (ANS) via ballast water discharge can cause significant economic and ecological damage. Numerous studies and reports have documented the impacts of such discharges, a select few of which include Bolch & Salas, 2007, Dobbs et al., 2006, Doblin et al., 2007, Drake & Lodge, 2007, Drake et al., 2007, Endresen et al., 2004, Knight et al., 1999, Reynolds et al., 1999, Roman, 2006, Ruiz et al., 2000a, Ruiz et al., 2000b, Smayda, 2007, and US EPA, 2001.

Ballast water is necessary for the safe operation of the vast majority of larger vessels to assist with vessel draft, trim, and stability. Almost all large vessels have ballast tanks, pumps, piping and other equipment dedicated to this purpose. In lieu of or in addition to such dedicated systems, some vessels may also carry ballast water in otherwise empty cargo holds. Ballast water is typically drawn in from, and discharged directly to, ambient waters. The ballast water discharge rate and constituent concentrations of ballast water from vessels will vary by vessel type, ballast tank capacity, type of deballasting equipment, the quality of the ambient water from which the ballast water is drawn, the amount and quality of residual water or sediment in the tank, the efficacy of any ballast water management practices and/or ballast water treatment employed, and other factors. Vessels may discharge anywhere from less than a hundred cubic meters of ballast to tens of thousands of cubic meters. For instance, passenger vessels have a representative ballast capacity of about 3,000 cubic meters (about 792,516 gallons) while ultra large crude carriers (ULCCs) representative ballast capacity is about 95,000 cubic meters (about 25,096,345 gallons) (ABS, 2010). The discharge rate of ballast water is generally proportional to the size of the tanks, although there are notable exceptions (e.g., bulk carriers on the Great Lakes are often designed to load and unload cargo and ballast water quickly).

Under current US regulation and permitting requirements (discussed in greater detail below), existing best management practices are required to help reduce the potential impacts of ballast water discharges. These include ballast water exchange[1] and saltwater

[1] "Ballast Water Exchange" means to replace the water in a ballast tank using either "Flow through exchange" or "Empty/refill exchange". "Flow through exchange" means to flush out "ballast water" by pumping in water from the "mid-ocean" or "coastal exchange zone" (as applicable) into the bottom of the tank and continuously overflowing the tank from the top until three full volumes of water has been changed to minimize the number of original organisms remaining in the tank. "Empty/refill exchange" means to pump out the "ballast water" taken on in ports, estuarine, or territorial waters until the tank is empty, then refilling it with water from the "mid-ocean" or "coastal exchange zone" (as applicable); when conducting

flushing[2] for certain vessels/voyages (collectively referred to as Ballast Water Exchange or BWE in this paper). These practices have been shown to offer some protection in mitigating the transfer and potential introduction of invasive species (Ruiz and Reid, 2007; McCollin et al., 2007a). While useful in reducing the presence of potentially invasive organisms in ballast water, BWE is not feasible for all vessels (e.g., vessels that cannot voyage off-shore), can have variable effectiveness, and in some circumstances may not be feasible due to vessel safety concerns.

One way to address these limitations associated with BWE is to require treatment of ballast water prior to discharge to meet an established standard for the concentration of living organisms. The United States Environmental Protection Agency (EPA) and the United States Coast Guard (USCG) both desire a stronger federal ballast water management program that will be more effective than current BWE-based requirements in preventing the ballast water-mediated spread of ANS (Silva and Salerno, 2009; Hanlon et al., 2010).

Several peer-reviewed publications have evaluated the efficacy of ballast water treatment systems, a small sampling of which include Gracki et al., (2002), Gregg & Hallegraeff, (2007b), McCollin et al. (2007b), Quilez-Badia et al. (2008), Perrins et al. (2006), Raikow et al. (2007), and Tamburri et al. (2002). Other reviews have used vendor supplied survey information or data to evaluate the availability and/or potential efficacy of these systems (Lloyds, 2010; Dobroski et al., 2009). However, there are also several complications associated with evaluating ballast water treatment technologies, including issues with sampling size, sufficient volume, and sufficient replicates (Lee et al., 2010), limited availability of valid third party data, potential uncertainties regarding data quality control, and logistical difficulties of demonstrating these systems work onboard ships. These complications are not trivial and affect the ability to evaluate the efficacy of ballast water treatment systems and, in some ways, how Agencies would be able to utilize existing effluent data (these issues are discussed in greater detail in Section 4).

EPA is specifically asking the committee to provide a written report assessing the availability and efficacy of ballast water treatment systems in neutralizing (killing or removing) living organisms contained in the ballast water that would otherwise be discharged.[3] The scope of ballast water treatment technologies we are asking the committee to consider includes both systems that have been indentified as currently

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empty/refill exchange, masters/operators should pump out as close to 100 percent of the “ballast water” as is safe to do so (adapted from 33 C.F.R 151.2025(b) (definition of “exchange”)).

[2] “Saltwater flushing” means the addition of “mid-ocean” or “coastal exchange zone” water to empty ballast water tanks; the mixing of the added water with residual ballast water and sediment through the motion of the vessel; and the discharge of the mixed water until loss of suction, such that the resulting residual water remaining in the tank has either a salinity greater than or equal to 30 parts per thousand (ppt) or a salinity concentration equal to the ambient salinity of the location where the uptake of the added water took place (adapted from 33 C.F.R. 401.30(f)(1)).

[3] EPA and USCG also recognize there is a need to better understand and relate the concentration of living organisms in ballast water discharges to the probability of introduced organisms successfully establishing populations in, and impacting, U.S. waters. EPA and USCG are currently sponsoring a separate study to address those types of issues by the National Academy of Sciences’ National Research Council (NRC) (see Appendix II).

available and systems that are known to be in the development process. Because of the current uncertainties and inherent complexities in determining the efficacy of ballast water treatment systems, an independent and credible review of the capabilities of such systems would be very helpful to EPA and USCG as they implement their respective authorities. A copy of the specific questions on these matters as included in the SAB charge is provided in Appendix I.

2. Regulatory Background [4]

Ballast water discharges from vessels are presently subject to regulation at the federal, state, and international level.[5] This section provides a general summary of such regulatory frameworks to provide the SAB with contextual background on the requirements currently in place or under development.

At the federal level, there are two principal statutes of interest: (1) the Nonindigenous Aquatic Nuisance Prevention and Control Act, as amended ("NANPCA," 16 U.S.C. §§ 4701 *et seq.*); and (2) the Federal Water Pollution Control Act (commonly referred to as the Clean Water Act or "CWA," 33 U.S.C. §§ 1251 *et seq.*). The principal ballast water management requirements under NANPCA and the applicable permit requirements that implement the Clean Water Act presently rely on use of mid-ocean BWE. However, as exchange is of variable effectiveness and cannot always be carried out due to safety concerns, efforts are underway at the federal level to develop a regulatory regime that will phase out use of exchange in favor of treatment to meet a ballast water discharge standard specified in terms of concentrations of living organisms per unit of volume of ballast water discharged.

Both NANPCA and the CWA preserve state authority to more stringently regulate ballast water discharges that occur in state waters. See, 16 U.S.C. § 4725 (NANPCA); 33 U.S.C. § 1370 (CWA). At the state level, regulation of ballast water discharges varies, not only as to whether there are applicable state requirements, but also as to the substantive content of such requirements where they do exist. For examples of state numeric limits for ballast water discharges, See, Table 1.

At the international level, ballast water discharges from vessels are primarily addressed under provisions established through the auspices of the International Maritime Organization (IMO). At present, the principal ballast water management practice at the international level involves the voluntary use of mid-ocean exchange. However, as will be further discussed, the text of a ballast water management Convention was adopted in February 2004. Once that Convention enters into force, it will in effect result in the phase out of the use of exchange in favor of treatment to meet a ballast water discharge

[4] Note that throughout this section, and where feasible in other sections, several references are hyperlinked for readers viewing this document electronically.
[5] Pursuant to § 657.1 of the Canada Shipping Act, Canada also has adopted Ballast Water Control and Management Regulations that are applicable in waters under Canadian jurisdiction, including Canadian waters of the Great Lakes.

standard specified in terms of concentrations of living organisms per unit of volume of ballast water discharged.

2.1. United States Federal Regulation

a) NANPCA

In light of growing awareness and concern about the impacts of invasive species introduced via discharges of ships' ballast water, Congress enacted NANPCA in November 1990. Pub. L. 101-646; 104 STAT 4761. As enacted in 1990, NANPCA provided for the USCG to issue regulations to prevent the introduction and spread of ANS into the Great Lakes through the ballast water of vessels.[6] In particular, the Act directed that these regulations require vessels carrying ballast water that enter a US port on the Great Lakes after operating beyond the exclusive economic zone ("EEZ") either carry out ballast water exchange prior to such entry or use environmentally sound alternative ballast water management methods that the USCG determines to be as effective as ballast water exchange in preventing and controlling ANS infestations (§ 1101(b) of P.L. 101-646; 104 STAT 4763). The Coast Guard issued final mandatory ballast water management regulations applicable to the Great Lakes in 1993 (Federal Register, Vol. 58, No. 66, April 8, 1993, page 18330).

Subsequent to NANPCA of 1990, Congress enacted the National Invasive Species Act ("NISA"), which amended and reauthorized NANPCA. Pub. L. 104-332; 110 STAT 4073. Among other things, the amendments made by NISA directed the USCG to address waters besides the Great Lakes by developing a voluntary national ballast water management program. Following development of that voluntary program, NISA directed the USCG to submit a report to Congress evaluating the effectiveness of the voluntary program. On June 3, 2002, USCG submitted that report to Congress, concluding that low participation in the voluntary program resulted in insufficient data for an accurate assessment of its effectiveness. This finding in turn triggered a requirement in NISA that the voluntary ballast water management program be made mandatory. As a result, the USCG issued final mandatory ballast water management regulations applicable to US waters. 69 Fed. Reg. 44952 (July 28, 2004).

The existing USCG ballast water management requirements specific to the Great Lakes are codified in regulations at 33 C.F.R. Part 151, Subpart C. Those regulations apply to "each vessel that carries ballast water and that after operating on the waters beyond the Exclusive Economic Zone during any part of its voyage enters the Snell Lock at Massena, New York, or navigates north of the George Washington Bridge on the Hudson River" (33 C.F.R. 151.1502). They generally require that such vessels either:

- Carry out an exchange of ballast water beyond the EEZ using exchange water from an area more than 200 nautical miles from any shore and more than 2,000 meters

[6] With respect to non-Great Lakes waters, NANPCA of 1990 did not establish ballast water management requirements, but instead called for several studies, including one to determine the need for controls on vessels entering US waters other than the Great Lakes. § 1102 of P.L. 101-646; 104 STAT 4764.

deep, such that any tank from which ballast water will be discharged contains water with a minimum salinity level of 30 parts per thousand;

- Retain the ballast water on board the vessel, with authority for the USCG to temporarily seal any tank or hold containing ballast water to ensure compliance; or
- Use an alternative environmentally sound method of ballast water management that has been submitted to, and approved by, the USCG prior to the voyage.

33 C.F.R. 151.1510(a).

Recognizing that vessels declaring No Ballast On Board or "NOBOB" (i.e., vessels with unpumpable residuals of ballast water) can nonetheless potentially introduce ANS if they uptake and then discharge ballast water after entry into the Great lakes, the USCG also issued a policy directing such vessels to conduct saltwater flushing prior to entry onto the Great Lakes. 70 Fed. Reg. 51831 (Aug. 31, 2005). Saltwater flushing requirements for "NOBOBs" entering the Great Lakes via the St. Lawrence Seaway were later made mandatory in regulations issued by the St Lawrence Seaway Development Corporation. 73 Fed. Reg. 9950 (Feb. 25, 2008).

The existing USCG ballast water management requirements for all US waters are codified in regulations at 33 C.F.R. Part 151, Subpart D. Those regulations, with limited exception, apply to all vessels, US and foreign, equipped with ballast tanks that operate in US waters and are bound for ports or places in the US. 33 C.F.R. 151.2005. With respect to Great Lakes vessels, both the Great Lakes-specific provisions of Subpart C as well as the relevant national provisions of Subpart D are applicable. See, 33 C.F.R 151.2040(a).

Among other things, these regulations establish a number of operational requirements with respect to ballast water uptake or discharge practices and other vessel related vectors for ANS, such as:

- Avoiding the discharge or uptake of ballast water in areas within or that may directly affect marine sanctuaries, marine preserves, marine parks, or coral reefs
- Minimizing or avoiding uptake of ballast water in areas known to have infestations or populations of harmful organisms, areas near sewage outfalls or dredging operations, or areas with poor tidal flushing
- Regular cleaning of ballast tanks to remove sediments
- Discharge only the minimal amount of ballast water essential for vessel operations while in the waters of the United States
- Rinsing of anchors and anchor chains remove organisms and sediments at their place of origin
- Removal of fouling organisms from hull, piping, and tanks on a regular basis
- Development of a ballast water management plan and training of master and crew on application of ballast water and sediment management and treatment procedures

33 C.F.R. 151.2035(a)

In addition, for those vessels carrying ballast water that was taken on in areas less than 200 nautical miles from any shore into US waters after operating beyond the EEZ, the regulations require at least one of the following ballast water management practices[7]:

- Perform complete ballast water exchange in an area no less than 200 nautical miles from any shore prior to discharging ballast water in U.S. waters;
- Retain ballast water onboard the vessel; or
- Use an alternative environmentally sound method of ballast water management that has been approved by the Coast Guard.
  33 C.F.R. 151.2035(b)

As previously noted, there are limitations inherent in a BWE-based framework. The USCG has issued a notice of proposed rulemaking that would gradually replace the current exchange-based regime with a regime requiring, treatment of ballast water to meet a concentration-based discharge standard – a standard that will increase in stringency over time. 74 Fed. Reg. 44632 (Aug. 28, 2009); See also, Table 1.

b) CWA

Section 301(a) of the CWA provides that "the discharge of any pollutant by any person shall be unlawful" unless the discharge is in compliance with certain other sections of the Act. 33 U.S.C. 1311(a). The CWA defines "discharge of a pollutant" as "(A) any addition of any pollutant to navigable waters from any point source, (B) any addition of any pollutant to the waters of the contiguous zone or the ocean from any point source other than a vessel or other floating craft." 33 U.S.C. 1362(12). A "point source" is a "discernible, confined and discrete conveyance" and includes a "vessel or other floating craft." 33 U.S.C. 1362(14). One way a person may discharge a pollutant without violating the prohibition in CWA § 301 is by obtaining authorization to discharge under a section 402 National Pollutant Discharge Elimination System (NPDES) permit (33 U.S.C. 1342). Under that section, EPA may issue a permit for the discharge of any pollutant, or combination of pollutants subject to certain conditions specified by the Act. The CWA requires that point source discharges meet technology-based effluent limitations representing the applicable levels of technology-based control and further requires water quality-based effluent limitations as necessary when the technology-based limitations are not sufficient to meet applicable water quality standards. For a more detailed discussion of technology-based and water-quality based effluent limits and NPDES permitting refer to chapter 5 and chapter 6 of EPA's NPDES Permit Writer's Manual (US EPA, 1996).

Shortly after the CWA was enacted, EPA promulgated a regulation that excluded discharges incidental to the normal operation of vessels from NPDES permitting. 38 Fed. Reg. 13528 (May 22, 1973). Following subsequent amendments, that regulation was codified at 40 C.F.R. 122.3(a) and identified several types of vessel discharges as being

[7] The regulations in Subpart D also contain certain exceptions that allow for the discharge of the minimum amount of unmanaged ballast water that is operationally necessary. However, in the case of vessels subject to the ballast water management requirements of Subpart C, the discharge of unmanaged ballast water into the Great Lakes or Hudson River is not allowed. See, 33 C.F.R. 151.2037; See also, 33 C.F.R. 401.30(g).

subject to NPDES permitting, but specifically excluded discharges incidental to the normal operation of a vessel (e.g., ballast water) from NPDES permitting, as follows:

> The following discharges do not require NPDES permits:
> (a) Any discharge of sewage from vessels, effluent from properly functioning marine engines, laundry, shower, and galley sink wastes, or any other discharge incidental to the normal operation of a vessel. This exclusion does not apply to rubbish, trash, garbage, or other such materials discharged overboard; nor to other discharges when the vessel is operating in a capacity other than as a means of transportation such as when used as an energy or mining facility, a storage facility or a seafood processing facility, or when secured to a storage facility or a seafood processing facility, or when secured to the bed of the ocean, contiguous zone or waters of the United States for the purpose of mineral or oil exploration or development.

In December 2003, that regulatory exclusion became the subject of a lawsuit in the U.S. District Court for the Northern District of California. In March 2005 the Court determined that the exclusion exceeded the agency's authority under the CWA. The Court subsequently issued an order in that case that vacated (struck down) the vessel NPDES exclusion in 40 CFR 122.3(a) as of February 6, 2009. As a result, discharges incidental to the normal operation of vessels, such as ballast water, that were excluded from NPDES permitting by that regulation became subject to CWA § 301's prohibition against discharge unless authorized by an NPDES permit. See generally, *Northwest Environmental Advocates et al. v. EPA*, 573 F.3d 1006 (9th Cir 2008).

In light of the court's decision, EPA developed two draft general NPDES permits for public comment addressing discharges incidental to the normal operation of vessels – one for commercial vessels and those recreational vessels greater than or equal to 79 feet, and one for recreational vessels less than 79 feet. 73 Fed. Reg. 34296 (June 17, 2008). Subsequently, Congress enacted two laws exempting certain vessels from NPDES permitting. The first of these, the "Clean Boating Act," amended the CWA to provide that discharges incidental to the normal operation of recreational vessels are not subject to NPDES permitting, and instead creates a new regulatory regime to be implemented by EPA and the USCG under new § 312(o) of the CWA. Pub. L. 110-188; 122 STAT 2650. The second of these enactments provided for a temporary moratorium on NPDES permitting for: (1) commercial fishing vessels regardless of size and (2) those other non-recreational vessels less than 79 feet in length. Pub. L. 110-299; 122 STAT 2995. However, that temporary moratorium is not applicable to ballast water discharges from such vessels.

As a result of the above legislation, EPA did not finalize the recreational vessel general permit and revised the other vessel general permit (for commercial vessel and large recreational vessels) to exclude recreational vessels. EPA's final vessel general permit (VGP) was issued in December 2008, and addresses 26 discharges incidental to the normal operation of commercial vessels, including ballast water. 73 Fed. Reg. 79473

(Dec. 29, 2008). The final VGP is accompanied by a detailed Fact Sheet explaining its terms and conditions.

With respect to ballast water discharges, the VGP includes, among other things, technology-based effluent limits that generally reflect the ballast water exchange requirements contained in the USCG regulations implementing NANPCA, as previously described. The VGP also includes several additional requirements not found in the USCG regulations, such as requirements for near-shore exchange by vessels engaged in Pacific near-shore voyages and a national requirement for saltwater flushing by NOBOBs. See, VGP § 2.2.3 and Fact Sheet § 4.4.3. In addition, the VGP includes water quality-based effluent limits to control discharges as stringently as necessary to meet applicable water quality standards. See, VGP § 2.3 and Fact Sheet § 4.5.

Under § 402(b)(1)(B) of the CWA, NPDES permits are issued for fixed terms that may not exceed five years. The existing VGP will expire on December 19, 2013.

2.2. State Regulation

A number of States (e.g., California, Michigan, Minnesota, Wisconsin) have specific State laws and regulations establishing ballast water discharge standards or management programs. In addition, other States without such specific ballast water related laws have included ballast water discharge standards as part of their Clean Water Act (CWA) section 401 certifications[8] of the VGP (e.g., Illinois (see, VGP § 6.10), Indiana (see, VGP § 6.11), New York (see, VGP § 6.22), Ohio (see, VGP § 6.23), Pennsylvania (see, VGP § 6.24)).

The standards contained in state requirements applicable to ballast water vary in terms of their stringency, schedules for implementation, and types of vessels covered. While this paper will not attempt to describe state requirements in detail, readers can refer to Table 1 for a summary of selected state ballast water discharge standards for organisms.

[8] As explained in the VGP Fact Sheet: "Part 6 of the final VGP identifies provisions provided to EPA by States and Tribes in their CWA § 401 certifications that the States and Tribes deemed necessary to assure compliance with applicable provisions of the CWA and any other appropriate requirements of State and Tribal law. *See* 33 U.S.C. 1341(d); 40 C.F.R. § 124.53(e)(1). Pursuant to CWA § 401(d), EPA has attached those State and Tribal provisions to the final VGP; those that constitute effluent or other limitations or monitoring requirements are enforceable conditions of the federal permit. *American Rivers, Inc. v. FERC*, 129 F.3d 99, 107 (2nd Cir. 1997)."

Table 1. Selected Ballast Water Discharge Standards for Organisms (Current as of June 28, 2010).

	Size: ≥ 50 micrometers (µm)*	Size: < 50µm, but ≥ 10 µm	Bacteria	Viruses	"Lakers**" Covered?	Compliance Date
IMO BW Treaty (Reg. D-2)	< 10 "viable" organisms per m^3	< 10 "viable" organisms per ml	*Vibrio cholera* < 1 CFU per 100 ml *E. coli* < 250 CFU per 100 ml *Intestinal enterococci* < 100 CFU per 100 ml	----	N/A	2009 – 2019 (varies by vessel construction date/BW capacity/survey date as per Reg B-3)
US Negotiating Position (BWM/CONF/ 13 & 14)	< 0.01 "living" organisms per m^3	< 0.01 "living" organisms per ml	*Vibrio cholera* < 1 CFU per 100 ml *E. coli* < 126 CFU per 100 ml *Intestinal enterococci* < 33 CFU per 100 ml	----	N/A	ASAP
USCG NPRM (74 FR 44632)	[PHASE 1 STANDARD] < 10 organisms per m^3	[PHASE 1 STANDARD] < 10 organisms per ml	[PHASE 1 STANDARD] *Vibrio cholera* < 1 CFU per 100 ml *E. coli* < 250 CFU per 100 ml *Intestinal enterococci* < 100 CFU per 100 ml	[PHASE 1 STANDARD] ----	Yes	On delivery for all vessels constructed on or after 01/01/12 All other vessels: varies by BW capacity & drydock cycle with latest compliance date of 1st drydock after 01/01/16
USCG NPRM (74 FR 44632)	[PHASE 2 STANDARD] < 1 organism per 100 m^3	[PHASE 2 STANDARD] < 1 organism per 100 ml	[PHASE 2 STANDARD] *Vibrio cholera* < 1 CFU per 100 ml *E. coli* < 126 CFU per 100 ml *Intestinal enterococci* < 33 CFU per 100 ml < 10^3 "living" bacterial cells per 100 ml	[PHASE 2 STANDARD] < 10^4 viruses or viral-like particles per 100 ml	Yes	On delivery for all vessels constructed on or after 01/01/16 All other vessels: 1st drydocking after 01/01/2016, unless prior installation of Phase 1 BW system, in which case 5 years from such installation

	Size: ≥ 50 micrometers (µm)*	Size: < 50µm, but ≥ 10 µm	Bacteria	Viruses	"Lakers**" Covered?	Compliance Date
CALIFORNIA (VGP 401 cert/State regulations)	[INTERIM STANDARD] 0 detectable "living" organisms	[INTERIM STANDARD] US negotiating position	[INTERIM STANDARD] *Vibrio cholera* IMO Reg D-2 # *E. coli* US negotiating position *Intestinal enterococci* US negotiating position $< 10^3$ bacteria per 100 ml	[INTERIM STANDARD] $< 10^4$ viruses per 100 ml	N/A	01/01/10 – 01/01/16 (varies by vessel construction date/BW capacity)
	[FINAL STANDARD] 0 detectable "living" organisms	[FINAL STANDARD] 0 detectable "living" organisms	[FINAL STANDARD] 0 detectable "living" organisms	[FINAL STANDARD] 0 detectable "living" organisms	N/A	01/01/2020
ILLINOIS (VGP 401 cert)	IMO Reg D-2 # (as daily average)	IMO Reg D-2 # (as daily average)	*Vibrio cholera*[a] ---- *E. coli* IMO Reg D-2 # (as daily average) *Intestinal enterococci* IMO Reg D-2 # (as daily average)	----	Yes	Constructed before 01/01/12: 01/01/16 Constructed after 01/01/12: Prior to operation
INDIANA (VGP 401 cert)	IMO Reg D-2 # [b] (as daily average)	IMO Reg D-2 # [b] (as daily average)	*Vibrio cholera*[a] ---- *E. coli* IMO Reg D-2 # (as daily average) *Intestinal enterococci* IMO Reg D-2 # (as daily average)	----	No	Constructed before 01/01/12: 01/01/16 Constructed after 01/01/12: Prior to operation

	Size: ≥ 50 micrometers (µm)*	Size: < 50µm, but ≥ 10 µm	Bacteria	Viruses	"Lakers**" Covered?	Compliance Date
MICHIGAN (VGP 401 cert/State permit)	Use a treatment process approved by MI DEQ	Use a treatment process approved by MI DEQ	Use a treatment process approved by MI DEQ	Use a treatment process approved by MI DEQ	No	01/01/07
MINNESOTA (VGP 401 cert/State permit)	IMO Reg D-2 # [b] (as daily average)	IMO Reg D-2 # [b] (as daily average)	*Vibrio cholera*[a] - *E. coli* IMO Reg D-2 # (as daily average) *Intestinal enterococci* IMO Reg D-2 # (as daily average)	----	Yes	Constructed before 01/01/12: 01/01/16 Constructed after 01/01/12: Prior to operation
NEW YORK (VGP 401 cert)	[INTERIM STANDARD] < 1 "living" organism per 10 m^3	[INTERIM STANDARD] < 1 "living" organism per 10 ml	[INTERIM STANDARD] *Vibrio cholera* IMO Reg D-2 # *E. coli* US negotiating position *Intestinal enterococci* US negotiating position	[INTERIM STANDARD] ----	Yes (vessels operating exclusively within Lakes Ontario and Erie are exempt)	01/01/12 (subject to case-by-case time extension)
	[FINAL STANDARD] Same as California #s	[FINAL STANDARD] US negotiating position	[FINAL STANDARD] *Vibrio cholera* IMO Reg D-2 # *E. coli* US negotiating position *Intestinal enterococci* US negotiating position Other bacteria: Same as CA interim #s	[FINAL STANDARD] Same as California interim #s	Yes (vessels operating exclusively within Lakes Ontario and Erie are exempt)	Constructed on or after 01/01/13 (subject to case-by-case time extension)

	Size: ≥ 50 micrometers (µm)*	Size: < 50µm, but ≥ 10 µm	Bacteria	Viruses	"Lakers**" Covered?	Compliance Date
OHIO (VGP 401 cert)	IMO Reg D-2 # [b] (as daily average)	IMO Reg D-2 # [b] (as daily average)	*Vibrio cholera*[a] ---- *E. coli* IMO Reg D-2 # (as daily average) *Intestinal enterococci* IMO Reg D-2 # (as daily average)	----	Yes (in part -- see column to right)	Lakers "launched" after 01/01/16: Immediate Non-Lakers "launched" before 01/01/12: 01/01/16 Non-Lakers "launched" after 01/01/12: Prior to operation
PENNSYL-VANIA (VGP 401 cert)	[INTERIM STANDARD] IMO Reg D-2 #	[INTERIM STANDARD] IMO Reg D-2 #	[INTERIM STANDARD] IMO Reg D-2 #	[INTERIM STANDARD] ----	Yes (vessels operating exclusively within Lake Erie are exempt)	Constructed before 01/01/12: 01/01/16 (subject to case-by-case time extension)
	[FINAL STANDARD] Same as California #s	[FINAL STANDARD] < 0.01 "viable" organism per ml	[FINAL STANDARD] *Vibrio cholera* IMO Reg D-2 # *E. coli* US negotiating position *Intestinal enterococci* US negotiating position Other bacteria: Same as CA interim #s	[FINAL STANDARD] Same as California interim #s	Yes (vessels operating exclusively within Lake Erie or PA waters are exempt)	Constructed after 01/01/12: Immediate (subject to case-by-case time extension)

	Size: ≥ 50 micrometers (µm)*	Size: < 50µm, but ≥ 10 µm	Bacteria	Viruses	"Lakers**" Covered?	Compliance Date
WISCONSIN (11/18/09 State permit)	< 1 "viable" [b] organisms per 10 m^3 (as daily average)	< 1 "viable" [b] organisms per 10 ml (as daily average)	*Vibrio cholera*[a] --- -*E. coli* US negotiating position (as daily average) *Intestinal enterococci* US negotiating position (as daily average)	----	No[c]	Constructed after 01/01/12:[d] Immediate Constructed before 01/01/12:[d] 01/01/14

* For some standards, the groupings actually are stated as organisms > 50 µm and organisms ≤ 50 µm but > 10 µm. For sake of simplicity, this table uses the IMO groupings throughout as the default column header.

** "Lakers" are vessels which generally voyage exclusively in the Great Lakes.

a Indicator microbes specified by State do not include *Vibrio cholera*.

b State has defined "viable" as living AND able to reproduce vs. IMO G8 (type approval) Guidelines (para 3.12) simply define viable as "living."

c Standards apply to oceangoing vessels only. However, WI permit does provide that Lakers shall implement BMPs as specified in § 2.2.3 of EPA's VGP (uptake and discharge practices).

d WI DNR intends to conduct a review by 12/31/10 to determine if BWT technology is available to meet the WI standards; if review concludes such BWT technology not available, the IMO Reg D-2 # will apply (subject to footnotes a & b). WI permit must be modified for this change to occur.

2.3. International Regulation

The role of ships' ballast water in introducing or spreading ANS has been a concern in the international community since the early 1990s. Beginning in 1991, the IMO, which is the principal UN body that addresses pollution from ships, adopted a series of resolutions containing recommended practices to help prevent the introduction of ANS by ballast water. The current resolution was adopted in 1997 and contains guidelines calling for mid-ocean ballast water exchange and other ballast water management practices. IMO Assembly Resolution A.868(20). (Many of the practices contained in that resolution are now, in effect, mandatory with respect to vessels with ballast tanks that operate in US waters by virtue of their inclusion in the previously discussed USCG ballast water regulations at 33 C.F.R. Part 151, Subpart D.)

Following adoption of that resolution in 1997, a ballast water working group was then regularly convened as part of the meetings of the IMO's Marine Environment Protection Committee ("MEPC"), with a charge of developing legally binding requirements for a ballast water management treaty. Over the course of such meetings, there was a gradual evolution away from reliance on ballast water exchange as the primary control mechanism to one requiring compliance with ballast water discharge standards stated in the form of concentrations of organisms per unit of volume of ballast water discharged. The culmination of this effort was a Diplomatic Conference held at the IMO in February 2004 which adopted the text of a ballast water management Convention. International Convention for the Control and Management of Ships' Ballast Water and Sediments, 2004 (hereinafter referred to as "the BW Treaty"). The BW Treaty will not enter into force until it has been signed (and, if necessary, ratified) by at least 30 countries representing not less than 35% of the gross tonnage of the world's merchant shipping. BW Treaty Article 18(1). The US is presently not a signatory, nor, as of the date of this paper, has the treaty entered into force internationally. Information on the status of IMO Conventions (as posted on the IMO website http://www.imo.org/home.asp) indicates that as of May 31, 2010, the BW Treaty has 25 Parties, representing 24.28% gross tonnage of the world's merchant shipping.

In effect, the provisions of the BW treaty will apply to Parties' commercial ships that engage in international voyages. See, BW Treaty Article 3. Subject to certain exceptions as set out in BW Treaty Regulations A-3 through A-5, such vessels must conduct ballast water exchange, and over time, according to a schedule dependent on vessel build date and ballast water capacity, comply with the Treaty's ballast water discharge standards. BW Treaty Regulation B-3. Those discharge standards address three size groupings of organisms, and as previously noted, are expressed as a concentration of organisms per unit of volume discharged. BW Treaty Regulation D-2; see also Table 1 (summarizing those standards). The three size groupings used in Regulation D-2 are based on minimum dimension and are as follows: 1) organisms >50 microns (to address macrofauna and zooplankton); (2) organisms >10 but ≤50 micron (to address phytoplankton); and (3) specified indicator bacteria (to address pathogens). During development of the 2004 treaty, the US took a negotiating position that the standards for

the two larger size groupings, ought to be 1,000 times more stringent than those ultimately adopted (see Table 1). However, the treaty does preserve the ability of Parties to adopt more stringent standards as necessary. BW Treaty Regulation C-1; see also, BW Treaty Article 2(3).

Under the Treaty, ballast water treatment systems are subject to a review and approval process, taking into account Guidelines developed by MEPC for such reviews. BW Treaty Regulation D-3. With respect to systems using "Active Substances" (biocidal agents) to comply with the BW Treaty, review and approval by the MEPC is conducted as to the environmental and safety aspects related to the system's use of biocides. The technical procedures for that review (commonly referred to as the "G9 Guidelines" or "G9 Procedure") are set forth in Resolution MEPC.169(57). Under the G9 Procedure, systems using Active Substances are subject to an initial "Basic Approval" and then a "Final Approval" by MEPC as to the environmental and safety aspects of the biocide's use. In addition, all systems (whether or not using Active Substances) are subject to a separate testing and approval process, this time by the Administration (typically the Flag state), as to the ability of the system to kill or remove organisms such that the results of the tests conducted on the system indicate it can meet the BW Treaty Regulation D-2 discharge standards (this type of testing is commonly referred to in IMO as "type-approval testing"). That type-approval testing is conducted under guidelines developed by the MEPC (the "G8 Guidelines") for evaluating compliance with the Regulation D-2 standards. MEPC Resolution MEPC.174(58). Typically, for those systems using Active Substances, final approval by MEPC under the G9 Procedure will precede flag state type-approval under G8.

Although the BW Treaty is not yet in force, a number of systems nonetheless have been submitted for review under the processes described above. The outcome of such reviews provides some third-party perspective regarding the development of the technologies so reviewed. Copies of such IMO documents have been provided to the SAB and are discussed in greater detail in Section 4.3.

3. General Overview of Ballast Water Treatment System Design

Treatment of ships' ballast water can take place either on the vessel or off the vessel following discharge of the ballast to a reception/treatment vessel (where the water would no longer be considered ballast water) or to a land-based reception facility. Treatment systems intended for onboard use by vessels discharging their ballast water directly into receiving waters have received the most attention by technology developers. Information in this overview section comes from the Lloyd's Register Review of Ballast Water Treatment Technology (February 2010) (hereinafter referred to as "Lloyd's Register Review"). While providing the most comprehensive summary of the current status of treatment technology, that review is based entirely on information supplied by the technology vendors. It is not based on an independent analysis or verification of claims made by the authors of the Lloyd's Register Review.

3.1. Treatment Processes

BWT systems are broadly based on three main processes: physical separation, biocidal treatment, and physical-chemical processes. Some BWT systems incorporate a combination of these processes. A brief description of each process is below.

Physical separation

While separation in the broader water treatment industry includes several different processes, for ballast water treatment it is essentially limited to screen and disk filters and/or hydrocyclonic separators. The former are almost all self-backwashing designs. Some media filters have been examined, but weight and cleaning issues have generally proved discouraging – although at least one novel concept for use of compressed crumb rubber has been published (Tang et al., 2006; Tang et al., 2009).

In general, hydrocyclones have not proven to be very effective, and only a few BWT systems using them are still in active development (Gregg et al., 2009). Separation is used as part of a process train to both remove larger organisms (generally, pore sizes of 25 – 100 um are used), and represent a balance between the need to remove organisms, the need to move large amounts of BW very rapidly (hundreds to many thousands of cubic meters per hour), and the need to reduce the amount of solids in ballast water to facilitate the action of various biocidal processes. As nominal pore size decreases, back-wash cycling increases, and effective pumping rates decrease. Lowered pumping rates can significantly slow cargo operations, with consequent economic impacts to carriers (vessel owners/operators) and shippers (the companies paying vessels to carry cargo).

At least one system developer (the Hitachi Ballast Water Purification System (“Clearballast”)) has incorporated flocculants or coagulants to facilitate the separation processes. This is particularly important for the use of hydrocyclones, which work on the basis of differential density, and most of the organisms that need to be removed from ballast water are not much denser than the water.

Biocidal treatment

Biocides used in BWT systems include chemicals such as oxidizing solutions (usually created by electrolytic processes using sea water as the source of ions), chlorine dioxide, and peracetic acid; non-oxidizing chemicals such as menadione/vitamin K (trade name SeaKleen©).

Systems using chemical biocides need to be designed to avoid discharging unwanted concentrations of residual biocide. A further issue with systems using chemical biocides is the potential for production of disinfection by-products, such as trihalomethanes and halo-acetic acids.

Many of the systems currently available or in development use chemical neutralizing agents prior to discharge. According to the Lloyd’s Register Review, most ozone and

chlorine systems neutralize treated ballast water before discharge, but some do not. Some treatment system developers rely on minimum hold times to provide an opportunity for sufficient degradation of residuals. In at least one case this has proven problematic for a type-approved system. The Hamman-SEDNA® ballast water treatment system using PERACLEAN® Ocean, which uses the proprietary biocide PERACLEAN® Ocean, a peracetic acid-based oxidant, was found to have significantly longer degradation rates in cold water than was expected, and the system has subsequently been taken off the market (Eason, 2010; Lloyds, 2010). This issue may not be unique to PERACLEAN® Ocean, as other biocides have also been found to have variable degradation rates dependent upon temperature (Landrum et al., 2003). This example provides an indication of the current limitations of the international approval process in that the G8 and G9 Guidelines were not subject to validation prior to their use. Furthermore, the challenge conditions that are specified in the G8 Guidelines may not provide for an adequate test of system performance under the full range of vessel operations for which the systems are intended. Temperature and salinity are two important examples, as it is possible under the current test procedures for systems to be type approved for all temperatures and salinities, while only being subjected to testing under a relatively narrow, and non-extreme, range of both. See Section 4.4 for additional discussion.

Physical-Chemical Processes

Physical-chemical processes used as means to kill organisms include Ultraviolet (UV) and ultrasonic (US) radiation, shear/cavitation; and deoxygenation (through lowered pressure via venturi or vacuum, or lowered partial pressure via gas sparging with inert gasses).

Most of the systems using UV employ medium pressure amalgam lamps, although some low-pressure systems exist. UV effectiveness depends on the applied UV dose/power of the lamp, however, the Lloyd’s Register Review states that this information has not been given by all suppliers. The transmissivity of the water being treated is another critical variable affecting the effectiveness of UV systems. Without accessory filtration, or other separation of solids, UV will not likely be as effective as necessary. While all UV-based systems to date employ front-end separation processes to improve transmission of UV, the challenge conditions required for type approval under the G8 Guidelines (TSS > 50 mg/L for brackish and fresh water; POC > 5 mg/L for brackish and fresh water) are far below the levels that can be encountered in estuarine harbors around the world (by 2 orders of magnitude for TSS).

Although most of the systems that currently exist are based on traditional water treatment processes, deoxygenation-based technologies have been specifically developed for ballast water treatment. Deoxygenation is accomplished through a variety of mechanisms, including pressure drops and gas sparging of inert gases. Deoxygenation may take longer than other processes (between one and four days seems likely, given current information), and thus represents the only type of technology where voyage length is a primary factor in process efficacy – although as mentioned above, some of the systems using chemical biocides include a minimum treatment time for sufficient action and degradation).

Deoxygenation may not be as broadly effective as other means of disinfection, as some organisms, particularly microorganisms, are able to survive for extended periods of time under low oxygen conditions.

3.2. Treatment Systems

Most treatment systems make use of 2 or more treatment processes in a train, for example, physical separation followed by some type of biocidal treatment(s). In practice, some systems, particularly those using separation and UV, are used on both uptake and discharge of ballast water. On uptake the full process train is engaged, with back-flushed solids from the filter being discharged overboard at the point of uptake. On discharge of the ballast water, the filter is bypassed and the water is exposed to the UV process immediately prior to discharge. An apparent assumption by many of the developers of these separation+UV systems is that there is no regulatory or environmental concern about the discharge of the filter backwash to the environment, since the water and sediment is "just being put back where it was taken up…". However, some jurisdictions have regulatory limits on suspended solids, and concentrations of other substances such as metals that such backwashing may exceed.

Several systems use 3 or more processes. At least one system exists for each of the following designs:

- Filter+UV+O_3
- Filter+US+O_3
- Filter+electrolysis+US
- Filter+deoxygenation+cavitation
- Filter+cavitation+electrolysis+O_3
- Shear+cavitation+O_3

The expected relative contributions of each process to the system efficacy, under the wide range of conditions under which the systems will be expected to work, is not always apparent in the information available for many of these systems.

3.3. Treatment System Requirements

Size (foot-print, volume, weight) and power requirements are key issues of concern for vessel operators considering the pros and cons of alternative treatment systems. For operational and logistical reasons, most treatment systems are intended for use in engine or pump rooms, where space is quite limited. Until the last year or two, provision of sufficient space in these areas for BWT systems have not been requirements in vessel designs. Consequently, installation often requires fitting the different modules into available spaces on an *ad hoc* basis. The larger the system, or the more inflexible its physical arrangement, the more negatively it is likely to be viewed by ship owners/operators. The availability of power is an issue because ships often have competing demands on available power during cargo operations when most ballast water

is taken on and discharged; and upgrading generator capacities to provide additional power necessary for ballast water treatment is an additional expense, both in capital costs and on-going fuel costs. This also results in other increased environmental impacts by increasing green house gas and other emissions. Consequently, the systems currently in play have a fairly narrow range of space and power requirements (Table I). However, it is important to keep in mind that in most cases, these numbers are for individual, or a small number of ganged, units. Many of these systems are designed to handle high flow rates by using multiple units, each rated for 200 – 300 m^3/h. In such situations, both space and power requirements would be significantly larger, although the relationship between flow and size is not necessarily linear.

Table 2. System Space and Power Characteristics for Ballast Water Treatment Systems (From Table 4 in Lloyd's Register Review).

	Footprint 200 m^3/h (m^2)	Footprint 2000 m^3/h (m^2)	Height (m)	Power (kW /1000 m^3)
Mean	7	21	3	68
Data Points	37	30	37	33
Min	0.3	1	1	0
Max	30	145	4.6	220

3.4. Treatment System Flow Capacities

While more than half of the vendors polled by Lloyd's claim to offer systems that can handle flow rates of >10,000 m^3/h, in many cases, this would be achieved through ganging multiple system units rated individually at 200-300 m^3/hr. However, systems are not generally tested for type approval in such ganged configurations and at such high flow rates.

3.5. Availability of Treatment Systems

Since the adoption of the IMO BWM Convention in 2004, and more particularly since the initial adoption of the G8 Guidelines for approval of ballast water management systems in 2005, a substantial number of treatment systems have been put into development globally (Figure 1). The apparent decline in new systems as shown in Figure 1 may reflect a real plateau in the number of systems, or may be an artifact of the process. Many systems do not come to public light until they apply for G9 Basic Approval by the MEPC, and it is at that time that estimates are made for their timelines for Final Approval by MEPC and G8 type approval by an Administration. For instance, applications for Basic Approval of five systems not identified in the Lloyd's Register Review of February 2010 have been submitted for consideration by MEPC in September of 2010; however, we have included these systems in Table 5 of this paper.

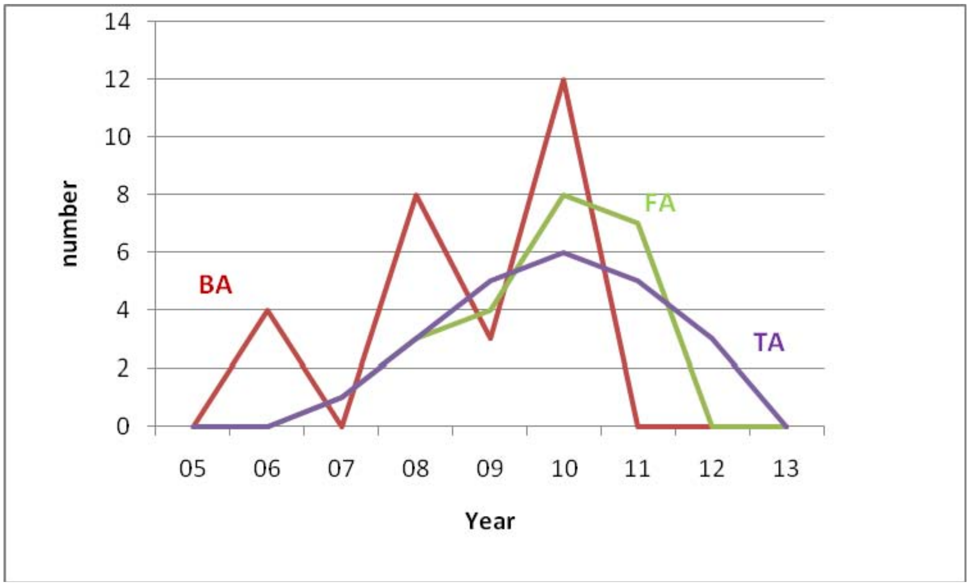

Figure 1. Number of systems approved by year.
BA= MEPC Basic Approval;
FA= MEPC Final Approval;
TA= Administration Type Approval.
All numbers from 2010 onwards are predictions made in February 2010. Data from Lloyd's Register Review (2010).

4. Technical Documents Provided to the Committee

Under the G8 Guidelines for type approval of ballast water management systems, ballast water treatment vendors must show that their systems meet the IMO Regulation D-2 Standards (see Table 1) in three consecutive valid shipboard test cycles and five consecutive valid land-based cycles to obtain type approval. Much of the living organism effluent data discussed below, particularly that collected in recent years, was gathered with the intention of seeking type approval from a given flag Administration. Other data were assembled in applications for acceptance of vessels in the vessel's Shipboard Technology Evaluation Program (STEP), discussed in greater detail on page 26 of this paper. Because this is pre-existing information developed under procedures not subject to our control, EPA nor Coast Guard staff cannot provide any quality assurance or quality control on any of the data or reports provided to the committee for this review, nor confirm the testing results reported actually meet the minimum guideline standard of passing three consecutive valid shipboard test cycles and five consecutive valid land-based cycles.

In order to assist with the committee's evaluation, EPA has provided numerous background documents discussing ballast water treatment systems and reporting results from their testing. For purposes of this paper, these documents have been divided into three major categories. The first category contains summary reports produced by parties evaluating the availability of existing ballast water treatment systems or their potential

efficacy (Section 4.1). These reports will help inform the committee about ballast water treatment systems in general, issues that may be present in their testing, and in some cases, provide summary data. These reports thus should be useful or provide introductory background to help the committee answer all seven charge questions.

The second category of background documents contains the primary performance data reports available to EPA and USCG (Section 4.2). These are land based and/or ship based testing reports, provided by either flag Administrations[9] or the manufacturers, to EPA or USCG. Performance reports or summaries of evaluations are available for 8 systems; many of these reports go into considerably more detail than the summary reports above. Many of these documents also give engineering details which may prove useful to the committee in answering questions 1c, 2, and 3 of the charge. However, detailed results discussing the quality of the effluent produced during the tests are notably absent from several of these available sources. Additionally, although we are aware that data have been collected on other additional systems, those data are not all available to us to provide to this committee: see additional discussion on page 30.

The third grouping of background documents are being provided to serve as a reference library for the committee (Section 4.3). With one exception, these documents have been prepared as reports for, or submissions to, IMO as part of the G9 Procedure review process and contain additional background on system design for committee members. An additional document written by a class society[10] is also included in this section. Because this is provided as background information for that purpose, we do not expect each committee member to review all the issues addressed in each of these documents.

Additionally, we discuss the potential availability of other information, which we would welcome committee members to introduce at the first committee meeting. Section 4.3 also contains a table (Table 5) which committee members can use as a guide to get a sense of all known ballast water treatment systems and where they stand in development and testing. For instance, if a treatment has been type approved, clearly data have been collected regarding treatment system performance, however, in many cases, those data are not currently available to us for supply to the committee.

All of the documents being provided to the committee are being supplied on a supplemental CD[11]. On that CD, an Excel index is provided which includes the system discussed, the title of the document, the date, and a hyperlink from that file to the targeted file. That index listing all documents supplied to the committee is also provided here as Appendix IV. We believe that committee members can use this resource as a tool to assist in their evaluation of the information provided, and to identify strengths and shortcomings in data availability to assist in answering the charge questions.

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[9] Flag Administration means the Government of a State whose flag the ship is entitled to fly (from 33 CFR § 169.5).

[10] The IACS defines class societies as "organizations that establish and apply technical standards in relation to the design, construction and survey of marine related facilities including ships and offshore structures."

[11] All documents provided on this CD and listed in Appendix IV are also included in a public docket. That docket, number EPA-HQ-OW-2010-0582, can be accessed at www.regulations.gov.

4.1. Third Party Reports or General Evaluations

There are six documents being provided to the committee which are third party reports or general evaluations. We believe that these documents will prove a significant resource for the committee by providing additional useful background information and an overview of system engineering designs, the complexities associated with evaluating these systems, and in the case of Dobroski et al., (2009a), summary data. These documents are:

- The February 2010 review prepared by Lloyd's Register and submitted to IMO on the current status of ballast water treatment technologies (Lloyds, 2010);
- A June 2010 report produced by American Bureau of Shipping (ABS), which examines ballast water treatment systems and discusses considerations for shipowners when they select and install these systems; (ABS 2010)
- A January 2009 assessment of the efficacy, availability and environmental impacts of ballast water treatment systems for use in California Waters prepared for the California State Legislature by staff from the California State Lands Commission (Dobroski et al., 2009a);
- An October 15, 2009, update for that California report (Dobroski et al., 2009b);
- A September 24, 2009, Circular prepared by the IMO Secretariat on the international approval status for various ballast water treatment systems that make use of Active Substances (IMO, 2009);
- Excerpts from a white paper titled "Density Matters," produced by Lee et al. (2010), which, in part, examined Dobroski's et al. analyses (2009a, 2009b) of systems that may be potentially available to meet the California Standard.

Lloyd's Register Review

The February 2010 Lloyd's Register Review discusses the status and availability of existing ballast water treatment systems. This review, based upon ballast water treatment manufacturer survey responses, addresses issues such as space requirements, system costs, system capacities, and systems' IMO approval status[12].

American Bureau of Shipping Ballast Water Treatment Advisory (ABS, 2010)

In June 2010, the classification society ABS published an Advisory on Ballast Water Treatment Technologies. Similar to the Lloyd's Register Review, the ABS Advisory gives an overview of treatment technologies and lists the status of various ballast water treatment systems. However, this document also goes into detail for factors vessel

[12] Note that we have provided an updated status as to ballast water approval of various systems by the IMO that is current as of June, 2010 in Table 4 in Section 4.3 of this document.

operators should consider when they purchase and install various systems such as corrosion and safety concerns, power ratings, total lifecycle costs, and ease of operation.

In addition to providing information targeted to shipowners, the appendix of that report also provides summary information on 14 different ballast water treatment systems, with links to each of those manufacturers' websites. The ballast water treatment systems for which it lists summary information are the Alfa Laval Ballast Water Management (PureBallast) System, Electro-Cleen™ System (ECS), OceanSaver® Ballast Water Management System, Venturi Oxygen Stripping (VOS) System, Hyde Guardian™ Ballast Water Treatment System, NK-O3 BlueBallast, OptiMarin Ballast System (OBS), Hitachi Ballast Water Purification (ClearBallast) System, GloEn-Patrol™ System, Resource Ballast Technologies System/Unitor BWTS, JFE BWMS, Hyundai Heavy Industries (HHI) EcoBallast System, RWO GmbH Marine Water Technology, Veolia Water Solutions & Technologies (CleanBallast) System and Greenship Sedinox® Ballast Water Management System. Note that the only systems for which we are able to provide primary data in Section 4.2 are the NEI Venturi Oxygen Stripping (VOS) system and the Hyde Marine (Hyde Guardian™) System (both underlined above).

2009 Assessment of the Efficacy, Availability and Environmental Impacts of Ballast Water Treatment Systems for Use in California Waters (Dobroski et al., 2009a)

The California State Lands Commission has prepared a report, as directed by the California Coastal Ecosystems Protection Act of 2006, as to "the efficacy, availability, and environmental impacts, including water quality, of currently available ballast water treatment technologies." (Dobroski et al., 2009a). The authors provide summaries of various treatment technologies, explanations of how they used vendor supplied data to evaluate those technologies, and conclusions on what they believe those data might mean for system availability. Based on their criterion of "at least one replicate in compliance with the performance standards" for each size grouping[13], irrespective of failure rate, the CSLC concluded that: "at least two treatment systems have demonstrated the potential to comply with California's performance standards."[14] However, the authors of the report take pains to note that: "the [California State Lands] Commission does not approve ballast water treatment systems" and that a "positive compliance assessment for the purpose of th[eir] report, however, does not relieve the vessel owner/operator of the responsibility of complying with California's performance standards for the discharge of ballast water." In addition to descriptions of ballast water treatment systems and their analyses, the authors provide vendor-supplied summary data in the Appendices, which may be useful for the committee in answering question 1 of the study charge.

Lee et al. (2010), discussed below, also describes the California report, which may further inform the SAB's analyses of technology availability.

[13] Excluding viruses: there are currently no known viable methods to test for viruses in ballast water effluent.

[14] California Performance Standards are listed in Table 1.

October 2010 Update: Ballast Water Treatment Technologies for Use in California Waters (Dobroski et al., 2009b)

In October, 2009, Dobroski et al. updated the previous version of the report. In this update, the authors evaluated additional data and concluded on the basis of the same criterion as in the first report that "at least seven ballast water treatment systems: Alfa Laval, Ecochlor®, SEDNA® ballast water treatment system using PERACLEAN® Ocean, Hyde Marine™, OceanSaver®, OptiMarin, and Techcross have demonstrated the capability to comply with California's performance standards for the discharge of ballast water." Similar to the first report, the authors note that the report does not: "constitute an endorsement or approval of any treatment system or system manufacturer by the Commission. The Commission does not approve ballast water treatment systems."

Unlike the 2009a full report, the interim report does not contain an appendix with the primary vendor-supplied data used in the analysis. According to CSLC staff, an updated version of this report, containing such data, may be available in summer of 2010. If finalized, that report would be made available at:
http://www.slc.ca.gov/Spec_Pub/MFD/Ballast_Water/Reports_Presentations.html.

IMO's International Convention for the Control and Management of Ships' Ballast Water and Sediments, 2004 - List of ballast water management systems that make use of Active Substances which received Basic and Final Approvals (BWM.2/Circ 23)

The September 24, 2009 IMO Secretariat Circular (BWM.2/Circ 23) provides a list of systems that have received G9 "Basic" or "Final" approval for their use of Active Substances, reflecting the decisions made up to and including the 59th meeting of the MEPC. Note that such approvals only apply to evaluating the potential risk from the biocides or by products used by the ballast water treatment system and do not evaluate the efficacy of the system in neutralizing living organisms. Hence, these approvals are not directly relevant in terms of showing the degree of treatment these systems can achieve; rather this document is being provided in this section to serve two purposes. First, the document provides a compendium of ballast water treatment systems which use Active Substances as of September, 2009. Second, it gives the reviewer a general sense of where these treatment systems are in the international approval process.

Additionally, so as to provide the most updated information possible, we have summarized subsequent G9 decisions that were made at the 60th meeting of the MEPC in the Table 3. This Table should be used as a supplement to the IMO Circular 23 to update the Active Substance approval status for the systems it addresses.

Table 3. Additional G9 Decisions Made Subsequent to BWM.2/Circ.23 (List of ballast water management systems that make use of Active Substances which received Basic and Final Approvals).

MEPC 60 G9 Decisions (March 26, 2010)[15]	
Basic Approval GRANTED	
Siemens SiCURE™ Ballast Water Management System	Proposed by Germany in document MEPC 59/2/11
Sunrui Ballast Water Management System	Proposed by China in document MEPC 60/2/3
DESMI Ocean Guard Ballast Water Management System	Proposed by Denmark in document MEPC 60/2/4
Blue Ocean Guardian (BOG) Ballast Water Management System	Proposed by the Republic of Korea in document MEPC 60/2/5
Hyundai Heavy Industries Co., Ltd. (HHI) Ballast Water Management System (HiBallast)	Proposed by the Republic of Korea in document MEPC 60/2/6
Kwang San Co., Ltd. (KS) Ballast Water Management System "En-Ballast"	Proposed by the Republic of Korea in document MEPC 60/2/7
OceanGuard™ Ballast Water Management System	Proposed by Norway in document MEPC 60/2/8
Severn Trent DeNora (BalPure®) Ballast Water Management System	Proposed by Germany in document MEPC 60/2/9
Basic Approval DENIED	
ATLAS-DANMARK Ballast Water Treatment System	Proposed by Denmark in document MEPC 60/2
Final Approval GRANTED	
GloEn-Patrol™ Ballast Water Management System	Proposed by the Republic of Korea in document MEPC 59/2/7
Resource Ballast Technologies System	Proposed by South Africa in document MEPC 59/2/10
JFE Ballast Water Management System (BallastAce)	Proposed by Japan in document MEPC 60/2/2
HHI Ballast Water Management System (EcoBallast)	Proposed by the Republic of Korea in document MEPC 60/2/1
Final Approval DENIED	
Ecochlor® Ballast Water Management System	Proposed by Germany in document MEPC 59/2/9

<u>Density Matters: Review of Approaches to Setting Organism-Based Ballast Water Discharge Standards (Lee et al., 2010).</u>

Density Matters (Lee et al., 2010) was specifically written to supply background information to the ongoing NRC study examining approaches to setting environmentally protective organism-based ballast water discharge standards[16]. There are two major

[15] Source: Report of the 60th Meeting of the Marine Environment Protection Committee, MEPC 60/22 (see discussions therein under agenda item 2).

[16] As discussed in the introduction to this paper, EPA and USCG are currently sponsoring a contemporaneous study led by the National Academy of Sciences' National Research Council (NRC) to examine that issue (see Appendix II). In that NRC study, EPA and USCG are requesting that the NRC broadly assess and make recommendations about various approaches for assessing the risk of establishment of new ANS from ballast water discharges.

sections of this paper which are relevant to the charge presented to the SAB. The first section discusses California's zero detectable discharge limit, and includes a discussion of the data evaluation in Dobroski et al. (2009a, 2009b). The second relevant section examines the statistical considerations in estimating concentrations of organisms larger than 50 microns in ballast water discharges. This section discusses statistical considerations which were not considered in development of the G8 Guidelines, and points to limitations in arriving at statistically significant or conclusive results based on data collected using methods consistent with the G8 Guidelines.[17] Additional extracts from this report include regulatory background and another table listing ballast water discharge standards to serve as additional references for the committee as needed. Additionally, the bibliography from the Lee et al. (2010) paper is included to serve as a reference list if needed.

4.2. Available Information for Specific Ballast Water Treatment Systems

In order to evaluate the efficacy of their ballast water treatment systems, several vendors have conducted land-based and/or ship-based evaluations of their systems. The reports provided to the committee fall into three categories: (1) those that include data reports from the testing of ballast water treatment systems provided to foreign Administrations in granting type approval under the BW Treaty and (2) data reports gathered by vendors in preparation to apply for type approval by a flag Administration, or (3) application packets prepared by the vendor and submitted to the USCG under the Shipboard Technology Evaluation Program (STEP). We believe the information in this section should help the committee answer questions 1, 2, and 3 of the charge.

As previously discussed, in order to be type-approved in terms consistent with the BW Treaty (International Maritime Organization, 2004), all ballast water systems (whether or not using Active Substances) are subject to a testing and approval process by an Administration (typically the Flag state or their authorized representative). These tests must demonstrate the ability of the system to kill or remove organisms such that the results of the tests conducted on the system indicate it can meet the Treaty's Regulation D-2 discharge standards (see Table 1). This type of testing is commonly referred to as "type-approval testing" and it is to be conducted under G8 Guidelines as set forth in resolution MEPC.174(58) (October 10, 2008). Many of the reports included below were prepared as part of a system manufacturer's preparations for seeking such G8 type-approval.

STEP was established by the US Coast Guard in 2004 as a way to encourage onboard ballast water treatment system development and testing. According to the US Coast Guard's: January 2, 2004, Navigation and Vessel Inspection Circular No. 01-04 for the STEP program:

[17] EPA and USCG are working toward finalizing an ETV Ballast Water Protocol, which will include updates to discharge testing recommendations to address issues associated with such monitoring complexity, including discussing statistical limitations.

> "STEP is intended to facilitate the development of effective BWT technologies, thus creating more options for vessel owners/operators seeking alternatives to ballast water exchange. Technology developers and vessel owners/operators have agreed on the need for incentives that will encourage the development of prototype treatment systems and shipboard testing. However, vessel owners/operators have expressed a reluctance to invest the resources to install and operate an experimental treatment system that might not meet discharge standards mandated by future regulations. To address this concern, vessels accepted into this program may be granted an equivalency to future ballast water discharge standard regulations, for up to the life of the vessel or the system, while the prototype system operates satisfactorily."

Systems entering the STEP program are generally in the advanced prototype stage. Hence, the data provided as part of STEP application may not be the most current data, and may also not reflect the most current changes to a system. For example, the Ecochlor® system, discussed below, has data in its STEP application, and then more current data in a land-based report. Between preparation of these two packages, the system underwent a modification, whereby a filter was added to increase system performance.

Systems for which Data Reports are Provided to the Committee

This section contains reports or papers on eight separate treatment systems, most of which contain at least some primary summary data. These reports generally do not contain significant raw data. This section is organized by treatment manufacturer, with each data report briefly introduced in that section. In many cases, we have not been able to obtain primary data reports for this committee's review. Generally, data on systems provided by willing flag Administrations are more thorough and developed than data provided under STEP, through peer reviewed papers, or simply flag Administration papers submitted to the IMO. The systems for which flag administrations either provided reports to the Coast Guard or made those reports publically available were Hamann AG (Sedna® BWMS), Hyde Marine, and NEI Treatment Systems LLC (all noted below). Echoclor®, NEI Treatment Systems LLC, and Severn Trent De Nora include information provided to the Coast Guard as part of the STEP application process. Additionally, Echoclor® contains a land based data report provided to EPA for purposes of this committee's review. Other information is from papers submitted to the IMO, peer-reviewed journal articles, and other published reports. The final subsection (discussing Oceansaver®, OptiMarin, and PureBallast) contains examples of several type approval certificates for certain systems for which we do not have data or summary reports from the flag Administration or the treatment system developer.

Table 4 lists each individual system for which we were able to provide the committee with additional specific information beyond their G9 summary reports or type approval certificates Type Approval Certificates, highlights how that system functions, and where that additional information can be found. Note that the names of systems which have been type-approved are shaded in green (see section 2.3 for discussion regarding type approval and Table 5 for additional treatment system specific information).

Table 4. Ballast Water Treatment Systems for which we have provided additional information.

Supplier System	*Technology*	*Have ship-based or land-based testing been conducted?*	*Are data available to this committee in this package (other than G9 summary reports or Type Approval Certificates)?*	*Document where Data can be found*
Alfa Laval Tumba AB (Pureballast)	Filtration, UV, TiO_2	Y[2]	N	Norwegian Maritime Directorate (2008)
Ecochlor Inc. (Ecochlor® BWMS)	Filtration, chlorine dioxide	Y	Y	Veldhuis et. al (2009) and Ecochlor (2006)
Environmental Technologies Inc.	Filtration, ozone, ultrasound[1]	Y	Y[3]	Dobroski et al. (2009a)
Greenship (Sedinox® BWMS)	Hydrocyclone, electrolysis/ electrochlorination	Y	Y	Siefert and Siers (2007)
Hamann AG (SEDNA® 250 BWMS)	Hydrocyclone, filtration, peracetic acid	Y	Y	Veldhuis and Fuhr (2008) and Eason (2010)
Hi Tech Marine Pty Ltd.	Heat[1]	Y	Y[3]	Dobroski et al. (2009a)
Hyde Marine; Lamor Corporation, LLC (Hyde Guardian)	Filtration, UV	Y	Y	ten Hallers et al (2009); Veldhuis et al (2009b); Wright (2009)
Marenco Technology Group, Inc.	Filtration, UV[1]	Y	Y[3]	Dobroski et al. (2009a)
Mitsui Engineering and Shipbuilding Co. Ltd. (SP-Hybrid BWMS Ozone Version)	Hydrodynamic shear, cavitation, ozonation[1]	Y	Y[3]	Dobroski et al. (2009a)
NEI Treatment Systems LLC (Venturi Oxygen Stripping (VOS))	Deoxygenation, cavitation	Y	Y	NEI (2007)
Oceansaver AS (OceanSaver® BWMS)	Filtration, deoxygenation, cavitation	Y[2,]	Y[3]	Norwegian Maritime Directorate (2009b), Dobroski et al. (2009a)
OptiMarin (OptiMarin Ballast System)	Filtration, UV[1]	Y[2,]	Y[3]	Norwegian Maritime Directorate (2009a) and Dobroski et al. (2009a)
Severn Trent De Nora (BalPure®)	Filtration, electrolysis/ electrochlorination, Cl neutralization	Y	Y[3]	Dobroski et al. (2009a)
Siemens (SiCURE™ BWMS)	Filtration, electrochlorination	Y	Y	Cangelosi, (2010a, 2010b)
Techcross (Electro-Clean System (ECS))	Electrolysis/ electrochlorination	Y	Y	Kim et al (2008)
Vitamar, LLC (Seakleen™)	Menadione / Vitamin K3 (as Seakleen™)[1]	Y	Y[3]	Dobroski et al. (2009a)

1 Information from Lloyd's Register Review (2010).
2 Land-based testing results, which to date, have not been given to US EPA or the US Coast Guard
3 Information on whether testing had taken place came from Dobroski et al. 2009 discussed in Section 4.1. Summary data only

Ecochlor® Inc. (Ecochlor® BWMS):

Three documents are included which describe the performance of the Ecochlor system. The first document is Section 4 of Ecochlor's 2006 STEP application and were provided to USCG to enroll a testing vessel into STEP (Echoclor, 2006). These data are from early shipboard testing of the full-scale Ecochlor system and do not reflect current system design (a filter has subsequently been incorporated in the system) or use the most current testing approaches. The second document by Veldhuis et al. (2009a) reports on the land-based testing results from the current design of the Ecochlor system. The authors of that report tested the Ecochlor system (including the mechanical filter) and noted that no regrowth of organisms in treated effluent was observed for more than 15 days. Environmental acceptability tests showed that the growth of plankton was not limited by the discharge water indicating that the discharged water was not significantly toxic. Furthermore, upon discharge, no residual effects of the chemical treatment to the receiving environment were observed. The third document is the final Environmental Assessment prepared by USCG to accept this system for a particular vessel into the STEP program (USCG, 2008).

Note that the Ecochlor® system has not yet been type-approved. Also, as noted in Table 5, the Ecochlor® system was denied final approval at a recent MEPC meeting, as recommended by GESAMP. The manufacturers of the system have submitted information to MEPC to seek this final approval and are preparing a package to submit for type approval of the system by the German Administration. See, MEPC 61/2/8.

Electro-Clean Ballast Water Management System:

Kim et al. (2008) discuss constructing a large test barge for land-based testing for Type Approval of ballast water management systems in the Republic of Korea. The paper describes the Electro-Clean System. This paper provides no data on the efficacy of the treatment system. The second document is the MEPC 59/INF.6 paper submitted by the Republic of Korea on the G8 type approval of this system. This paper notes that the system has ‘passed’ various components of testing, without discussing methods in depth or giving any specific results. Also note that this MEPC paper includes the table of contents for a more detailed report; however, at this time, we do not have a copy of these results.

Greenship’s Sedinox® ballast water treatment system:

A single document for the Greenship (Sedinox® BWMS) is included here (Siefert and Siers, 2007). This short 10 page report, published in 2007, described the land based testing for discharges from a moored vessel utilizing the Greenship ballast water treatment system.

Note that the Greenship Sedinox® BWMS has received IMO G9 Basic and Final approval, but has not yet received type approval.

Hamann AG (Sedna® BWMS)[18] (note: recently removed from the market):

Four documents in this section reference the Hamann AG (Sedna®) system. The Hamann AG (Sedna®) system uses a hydrocyclone to separate out some solids (potentially including living organisms) and then treats the less turbid water with a proprietary biocide known as Peraclean®. The first document, Siefert and Siers (2007), is a summary data report. The second document, the Veldhuis and Fuhr (2008) report, describes the land-based tests which were run on the Sedna® system, and provides some summary data on the residual discharge. The researchers in this report also found that there were no residual biocidal effects and the Active Substance was found to decompose in 24 hours. After 5 days in seawater tests, the authors noted a slight but insignificant effect from remaining acetic acid.

However, there were several questions regarding the potential toxicity of Peraclean® in coldwater and freshwater ecosystems. Further testing revealed that Peraclean® remained toxic in these environments, and Hamann subsequently pulled this treatment system from the market (Eason, 2010; Lloyds, 2010). Hence, though this treatment system received G9 Basic and Final approval, and was type-approved under the G8 Guidelines, it was later found to pose an unacceptable ecological risk.

Even though the Hamann AG system has been removed from the market, we have included these data here for two purposes. First, this data report adds another example of primary summary data for the committee to consider in what might be possible for existing treatment systems. Secondly, it also serves as an example that, even though treatment systems undergo significant toxicological testing and G9 review, they may still be found to cause unacceptable secondary environmental impacts in receiving waters at a later date due to the biocide residual discharge.

Hyde Marine Lamor Corporation, LLC[19] (Hyde Guardian™):

Five documents are included which exclusively discuss the Hyde Marine System. The first document does not discuss the efficacy of the system in neutralizing living organisms, instead, ten Hallers et al. (2009) provides a description of how the system works and its use of filtration and UV treatment. The report further discusses the risk to safety of the ship, ship integrity, if the system can be installed safely in a hazardous area, corrosivity, risk for fire and explosion, the absence of risk from chemicals (there are no active substances used), risk to the crew, risk to human health, risk to the aquatic environment, and noise level. The report's authors also examine information on potential byproducts and end products, their toxicological profile, and the actual presence or absence of those products under potential conditions the system might meet. The authors note the environmental benefits of the Hyde System not using Active Substances.

[18] Note that the data for this system were made publicly available by the German Government as a flag Administration.
[19] Note that the data for this system were made publicly available by the British government as a flag Administration.

The second document by Veldhuis et al. (2009b) summarizes results from tests run on the Hyde Guardian™ system. The authors report that treatment by the system was found not to deactivate the entire plankton community, and environmental acceptability tests showed that growth of organisms was not limited by the discharge water (and therefore, did not have notable toxicity). The third document by Wright (2009) summarizes the results of shipboard testing of the Hyde System.

The final two documents are the MEPC 59/INF.20 report where the United Kingdom reports to the IMO that the Hyde System has been type approved by that flag Administration and a copy of the type approval certificate.

<u>NEI Treatment Systems LLC (Venturi Oxygen Stripping (VOS))</u> [20]

Six documents are provided to support the analysis of the NEI Treatment Systems LLC, representing one of the more complete data packets available to the committee. These documents generally discuss results for both the efficacy of the system at neutralizing organisms and its potential toxicity, testing methods, and give an overview of the engineering of the systems. One document is the USCG STEP Application (NEI, 2006). This application contains the study plan for evaluation onboard a test vessel, a description of how the system functions, and other information including discussions of vessel and crew safety. A second document is the application for type approval certification submitted by NEI to the Liberian Flag Administration. Similar to the STEP application, this document contains an overview of how the system functions and testing results regarding the efficacy of the treatment system, among other things. A third document, Tamburri and Ruiz (2005), is a peer reviewed paper which provides summary data of the efficacy of the NEI system. The fourth and fifth documents are acute and chronic toxicity reports (Burton et al., 2008; Fischer et al., 2009). These short reports summarize the results of Whole Effluent Toxicity testing of effluent from lab scale NEI units. The final document contains three type approval certificates (Liberia, Malta, and The Marshall Islands), which show that this system has received flag Administration approval from three separate Administrations.

<u>Severn Trent De Nora (BalPure®)</u>

Three documents are provided which discuss the Servern Trent De Nora BalPure® system. The first is an application package the company submitted to the State of Washington to obtain approval to use the system in that State's waters (Severn Trent De Nora, 2005). That package contains detailed information about how the company's BalPure® system works, and alludes to work conducted which examined the efficacy of that system in land-based testing. The second document (Herwig, 2004), a mesocosm-scale study, examines the efficacy of this type of system at eliminating certain organisms, and whether the residuals from the system contain significant total residual oxidant (TRO). The third document is the Environmental Assessment prepared for the USCG discussing the design of the system and its potential impacts on the aquatic environment

[20] Note that much of the data for this system were provided by the Liberian Government as a flag Administration.

(Volpe, 2009). Though these documents do not provide the level of discharge data provided by other systems discussed in this section (e.g., NEI, Hyde Marine), these documents provide engineering overviews, and some early monitoring results collected for this system. Additionally, note that summary data on the BalPure® system are presented in Dobroski et al., 2009a.

Siemens (SiCURE™ BWMS)

Two documents are included which summarize treatment efficacy from the Siemens (SiCURE™ BWMS) ballast water treatment system (Cangelosi, 2010a; Cangelosi 2010b). In Cangelosi (2010a), the Siemens SiCURE™ system was evaluated for its ability to remove living organisms from ballast water, meet the BW Treaty Regulation D-2 discharge standards after a 5-day holding time, and discharge non-toxic water after a 5-day retention period. Researchers noted that further testing would be needed to characterize residual toxicity after a 5-day retention period, but that no effect was detected during these trials. In Cangelosi (2010b), the author discusses ballast water management system's use in the Great Lakes. The researchers discussed what they deemed "below the radar" zooplankton, and other issues related to State ballast water discharge limits compared to the Regulation D-2 standard. In this report, the authors note that this system likely needs a neutralization step for residual chlorine for ballast water discharges into the Great Lakes from Great Lakes confined vessels (Lakers) due to short voyage times.

Note that as of the writing of this paper, this system has received G9 Basic Approval, but has not yet received such Final Approval, nor has it been type approved under the G8 Guidelines by a flag Administration.

Oceansaver®, OptiMarin, and PureBallast:

Oceansaver®, OptiMarin, and PureBallast are three separate ballast systems which have all received type approval from their respective flag Administrations (see Table 5). As of June 15, 2010, Oceansaver® has announced that they have system contracts or signed letters of intent for 11 ballast water treatment systems for Very Large Crude Carriers (Maritime Executive, 2010). According to the manufacturer, this represents approximately 40 million dollars of anticipated ballast water treatment system installation. In short, this indicates that this system has obtained some degree of commercial desirability.

Two documents are available for Oceansaver®, neither of which contain primary summary data. One document is the MEPC 59/INF.17 submitted by the government of Norway describing that they type approved the Oceansaver® system. The second document is a type approval certificate from the Norwegian flag Administration (Norwegian Maritime Directorate, 2009b).

However, neither the government of Norway nor the Norwegian Institute for Water Research testing facility (NIOZ) have released sampling methodologies or data from their

sampling to USCG[21]. As such, EPA and USCG have not been able to independently evaluate data on the efficacy of these ballast water treatment systems.

For both the Alfa Laval PureBallast (Norwegian Maritime Directorate, 2008) and OptiMarin (Norwegian Maritime Directorate, 2009a) systems, only the type approval certificates are available. The Alfa Laval PureBallast system was granted type approval by the flag Administration of Norway in 2008 while the OptiMarin system was granted type approval in 2009 (see Table 5).

4.3. G9 Papers and Other Information

Several papers (including G9 applications and resulting technical reviews) have been assembled for the committee collectively labeled “G9 Papers.” These papers are included to serve as a reference section for committee members[22]. As discussed above in Section 2.3, systems using “Active Substances” are subject to approval by the IMO’s Marine Environment Protection Committee (MEPC) under BW Treaty Regulation D-3 as to the environmental and safety aspects related to the system's use of biocides. The G9 Procedure for that review is set forth in MEPC resolution MEPC.169(57) (April 4, 2008). Under the G9 Procedure, systems using Active Substances are subject to an initial “Basic Approval” and then a “Final Approval” by MEPC as to the environmental and safety aspects of the active substances as used in that system.

In addition to discussing the environmental and safety impacts of the biocide’s use[23] (which is beyond the direct scope of the committee’s charge), each of the G9 Papers outlines how a given ballast water treatment system functions, and in some cases, its expected mechanism of neutralizing living organisms. Hence, these documents might have some utility in providing general information on systems’ designs.

Table 4 below was derived in large part from these MEPC documents and lists 52 different ballast water treatment systems. Systems for which Primary Data Reports are available in Section 4.2 are underlined under the “Supplier System” column. The reference library of MEPC documents contains the MEPC documents describing 26 of these systems. The reference library also contains several meeting reports which, in

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[21] Despite several requests to the Flag Administrations, neither Norway nor the Republic of Korea have provided test reports for systems granted type approval by those countries

[22] We do not expect committee members to review all of these documents, nor do we expect feedback on their quality, but we are making them available so committee members could read more about ballast water treatment systems with biocides if they need additional general information about a given treatment system’s design.

[23] Ballast water treatment systems are designed to kill living organisms – if not properly managed, these systems may discharge harmful levels of residuals into neighboring waters. We have not asked the committee to delve into these issues merely so as not to distract from answering the important question at hand – what is the status of technology for effectively and practically killing or removing living organisms before discharge. However, the committee should be cognizant that some of these systems use biocides; the use of which must be carefully managed so as not to create one environmental problem while solving another.

addition to discussing these 26 systems, discuss many of the other systems listed in Table 5.

As part of these reference documents, we are also including an additional document developed for vessel owners about how to approach purchase and installation of a ballast water treatment system which was produced by a vessel classification society (ClassNK, 2010). Like many of the documents in Section 4.1, the document provides background information on the 2004BW Treaty, testing of systems, and generalized information about how treatment system works. The document also contains frequently asked questions which illustrate some of the complexities with installing these systems onboard existing vessels.

As noted above, G8 type approval has been granted for several systems for which neither EPA nor USCG have full primary data packs. As shown in Table 5, ten systems currently have type approval; however, as discussed in Section 4.2, we only have type approval packages for 3 of these systems. Because these systems have been type approved, efficacy data on the numbers of living organisms must exist which would have been provided to the flag Administrations granting that type approval.[24] Additionally, numerous systems, similar to Ecochlor® as discussed in section 4.2, are advanced in their development: system designers and developers have likely taken a reasonable level of sampling data for these systems before continuing to invest millions of dollars in their development. We have not been able to gather and consolidate all existing, available data for the committee. Provided that such data are taken by a credible third party within the relatively recent past using appropriate test methods, we would encourage introduction and use of these data for the committee's deliberations. We would particularly encourage use of these supplemental data for those systems which are type approved by a flag Administration. In short, we recognize that there must be relevant additional data besides that which we have been able to obtain and provide to the committee. If committee members have access to credible additional data, we would encourage their use to inform the committee's deliberations.

[24] Certain system manufacturers and testing facilities are treating the data collected and methods used as proprietary or confidential information, which unfortunately impedes additional independent evaluation of the availability and efficacy of those systems.

Table 5 Summary Status of Ballast Water Treatment Systems which use Active Substances (Current as of June 16, 2010, through MEPC 61/2/13).

Supplier System	*Process*	*G9 Active Substance Approval (Basic)*[1]	*G9 Active Substance Approval (Final)*[1]	*G8 System Approval*[2]	*Test Site*	*Type Approval*	*Units Installed*[3]	*Projected Production (Units/Year)*[3]	*Notes*
21st Century Shipbuilding Co., Ltd. (ARA Ballast)	Filtration, plasma arc shockwave, and ultraviolet	**March 2010** MEPC 60/22 ¶ 2.4.4 MEPC 60/2/12 Annex 8 [GESAMP] MEPC 60/2/5	MEPC 61/2/5	-	Tong-Yeong, Korea	-	-	-	The name of this system was changed from "Blue Ocean Guardian BWMS" to "ARA Ballast;" see MEPC 61/2/5 ¶ 5.
Alfa Laval Tumba AB (Pureballast)	Filtration and ultraviolet-TiO_2	**July 2007** MEPC 56/23 ¶ 2.8 MEPC 55/2/5	**July 2007** MEPC 56/23 ¶ 2.8 MEPC 56/2/2 Annex 5 [GESAMP] MEPC 56/2/1	April 2008	NIVA	**27 June 2008** Norway MEPC 58/2/12 Annex ¶ 6.3	5	-	MEPC 53/2/6, MEPC 53/2/14, MEPC 53/2/16, MEPC 55/INF.3, MEPC 57/2/9
AQUA Eng. Co., Ltd. (AquaStar BWMS)	Filtration and electrolysis-electrochlorination	MEPC 61/2/1	-	-	-	-	-	-	The "Smart Pipe Unit" forms part of the AquaStar Ballast Water Management System.
Aquaworx ATC GmbH (AquaTriComb™ BWTS)	Filtration, ultraviolet, and ultrasound	**July 2009** MEPC 59/24 ¶ 2.5.3 MEPC 59/2/19 Annex 6 [GESAMP] MEPC 59/2/8	-	-	-	-	-	-	
ATG Willand	Filtration and ultraviolet	-	-	-	-	-	1	-	
ATLAS-DANMARK (ATLAS-DANMARK BWTS)	Filtration and "mixed oxidant approach" (oxidation); electrolysis	MEPC 60/22 ¶ 2.6 MEPC 60/2/12 Annex 4 [GESAMP] MEPC 60/2	-	-	-	-	-	3	This system uses ANOLYTE and CATHOLYTE.
Auramarine	Filtration and ultraviolet	-	-	Land (Jan-10)	NIVA	-	0	Unlimited	
Brillyant Marine LLC	Electric pulse	-	-	-	Maryland	-	0	Unlimited	

Supplier System	*Process*	*G9 Active Substance Approval (Basic)*[1]	*G9 Active Substance Approval (Final)*[1]	*G8 System Approval*[2]	*Test Site*	*Type Approval*	*Units Installed*[3]	*Projected Production (Units/Year)*[3]	*Notes*
China Ocean Shipping (Group) Company (COSCO)/Tsinghua University (BlueOcean Shield BWMS)	Hydrocyclone, filtration, and ultraviolet	**July 2009** MEPC 59/24 ¶ 2.5.1 MEPC 59/2/16 Annex 7 [GESAMP] MEPC 59/2/2	-	-	-	-	-	-	
Coldharbour Marine	Deoxygenation and cavitation	-	-	-	NIOZ	**-**	-	-	
DESMI Ocean Guard A/S (DESMI Ocean Guard BWMS)	Filtration, ultraviolet, and ozonation	**March 2010** MEPC 60/22 ¶ 2.4.3 MEPC 60/2/12 Annex 7 [GESAMP] MEPC 60/2/4	-	-	DHI	-	-	-	
Ecochlor Inc. (Ecochlor® BWMS)	Filtration and ClO_2	**October 2008** MEPC 58/23 ¶ 2.6.3 MEPC 58/2/8 Annex 5 [GESAMP] MEPC 58/2/2	MEPC 61/2/8 MEPC 60/22 ¶ 2.11 MEPC 60/2/11 Annex 5 [GESAMP] MEPC 59/2/9	Land (Jun-08) Sea Ongoing	NIOZ	-	2	100	This system uses Purate®. Ecochlor® BWMS is installed on board Atlantic Container Lines' ATLANTIC COMPASS and Matson Shipping's MOKU PAHU as a part of the USCG STEP (73 FR 72814; 73 FR 72819). MEPC 53/2/14, MEPC 53/2/16
Electrichlor Hypochlorite Generators Inc.	Filtration and electrolysis-electrochlorination	-	-	-	-	-	3	240	
Environmental Technologies Inc.	Filtration, ozone, and ultrasound	-	-	-	-	-	0	-	MEPC 53/2/14
Envirotech and Consultancy Pte. Ltd. (BlueSeas BWMS)	Filtration and electrolysis-electrochlorination	MEPC 61/2/12	-	-	-	-	-	-	
ERMA FIRST E.S.K. Engineering Solutions S.A. (ERMA FIRST BWMS)	Filtration, hydrocyclone, and electrolysis-electrochlorination	MEPC 61/2/11	-	-	-	**-**	-	>100	ERMA FIRST E.S.K. Engineering Solutions S.A. is associated with Environmental Protection Engineering S.A. (MEPC 61/2/11 Annex, ¶ 1.1).

Supplier System	Process	G9 Active Substance Approval (Basic)[1]	G9 Active Substance Approval (Final)[1]	G8 System Approval[2]	Test Site	Type Approval	Units Installed[3]	Projected Production (Units/Year)[3]	Notes
Gauss	Filtration and ultraviolet	-	-	-	-	-	0	-	MEPC 53/2/11 Annex 2, MEPC 53/2/16, MEPC 56/2/10
Greenship (Sedinox® BWMS)	Hydrocyclone and electrolysis-electrochlorination	**October 2008** MEPC 58/23 ¶ 2.6.2 MEPC 58/2/7 Annex 6 [GESAMP] MEPC 57/2/7	**July 2009** MEPC 59/24 ¶ 2.8.4 MEPC 59/2/19 Annex 5 [GESAMP] MEPC 59/2/6	Land (Oct-07) Sea (Jun-08)	Harlingen	-	2	Unlimited	MEPC 53/2/16
Hamann AG (SEDNA® 250 BWMS)	Filtration and Peraclean®	**March 2006** MEPC 54/21 ¶ 2.8 MEPC 54/2/12 Annex 5 [GESAMP] MEPC 53/2/12	**April 2008** MEPC 57/21 ¶ 2.16 MEPC 57/2/10 Annex 7 [GESAMP] MEPC 57/2/5	June 2007	NIOZ	**10 June 2008** Germany MEPC 58/INF.17	2	65	This system uses Peraclean® Ocean. MEPC 53/2/11 Annex 3, MEPC 53/2/14, MEPC 53/2/16, MEPC 55/2/17 Annex 5, MEPC 56/2/10, MEPC 57/2/9. This system has been withdrawn from the market (Lloyd's, 2010).
Hi Tech Marine Pty Ltd.	Heat	-	-	Land (Feb-03)	Sydney	-	0	-	
Hitachi (Hitachi Ballast Water Purification System - ClearBallast)	Filtration and pre-coagulation (enhanced flocculation)	**April 2008** MEPC 57/21 ¶ 2.11 MEPC 57/2 Annex 5 [GESAMP] MEPC 57/2/2	**July 2009** MEPC 59/24 ¶ 2.8.3 MEPC 59/2/19 Annex 4 [GESAMP] MEPC 59/2/5	Land (Jun-08) Sea (Jul-08)	-	***5 March 2010*** *Japan*	0	50	MEPC 54/2/9, MEPC 55/2/15
Hyde Marine; Lamor Corporation, LLC (Hyde Guardian)	Filtration and ultraviolet	N/A	N/A	Land (Apr-09) Sea (Apr-09)	NIOZ	**29 April 2009** UK MEPC 59/INF.20	15	500	This system is installed on board Princess Cruise Lines' CORAL PRINCESS as a part of the USCG STEP (73 FR 72817). MEPC 53/2/14, MEPC 53/2/16
Hyundai Heavy Industries (HHI) (EcoBallast)	Filtration and ultraviolet	**July 2009** MEPC 59/24 ¶ 2.5.2 MEPC 59/2/16 Annex 8 [GESAMP] MEPC 59/2/4	**March 2010** MEPC 60/22 ¶ 2.13 MEPC 60/2/1 MEPC 59/24 ¶ 2.7 MEPC 59/2/16 [GESAMP] ¶ 4.7	Land (2008) Sea (2009)	HHI	-	1	98	

Supplier System	Process	G9 Active Substance Approval (Basic)[1]	G9 Active Substance Approval (Final)[1]	G8 System Approval[2]	Test Site	Type Approval	Units Installed[3]	Projected Production (Units/Year)[3]	Notes
Hyundai Heavy Industries (HHI) (HiBallast)	Electrolysis-electrochlorination and *optional* filtration	**March 2010** MEPC 60/22 ¶ 2.4.5 MEPC 60/2/16 Annex 4 [GESAMP] MEPC 60/2/6	-	Land (2009)	HHI	-	1	165	
JFE Engineering Corporation (JFE BWMS (BallastAce))	Filtration, chlorination, and cavitation	**October 2008** MEPC 58/23 ¶ 2.6.1 MEPC 58/2/7 Annex 5 [GESAMP] MEPC 57/2/8	**March 2010** MEPC 60/22 ¶ 2.7.3 60/2/12 Annex 5 [GESAMP] MEPC 60/2/2	Land (Mar-09) Sea (Sep-09)	NIVA	-	1	300	JFE and Toagosei Group were originally categorized separately. The suppliers were combined because: 1. JFE is partnered with TG Corporation (Lloyd's, 2008 and 2010), the manufacturer of TG BallastCleaner; and 2. Language used in MEPC 60/2/2 indicates that the companies are developing one treatment system (the JFE BWMS). MEPC 55/2/15. This system uses TG Ballastcleaner and TG Environmentalguard.
Kuraray Co., Ltd. (Kuraray BWMS)	Filtration and calcium hypochlorite	MEPC 61/2/6	-	-	-	-	-	-	
Kwang San Co., Ltd. (KS) (En-Ballast)	Filtration and electrolysis-electrochlorination	**March 2010** MEPC 60/22 ¶ 2.4.6 MEPC 60/2/16 Annex 5 [GESAMP] MEPC 60/2/7	-	-	-	-	-	-	
M H Systems	Deoxygenation with inert gas and CO_2	-	-	-	SIO	-	0	300	
Mahle NFV GmbH	Filtration and ultraviolet	-	-	Land (2009) Sea (2010)	NIOZ	-	1	At least 50	
Marenco Technology Group, Inc.	Filtration and ultraviolet	-	-	2007[4]	MLML	-	1	240-360	MEPC 53/2/14

Supplier System	Process	G9 Active Substance Approval (Basic)[1]	G9 Active Substance Approval (Final)[1]	G8 System Approval[2]	Test Site	Type Approval	Units Installed[3]	Projected Production (Units/Year)[3]	Notes
Mexel Industries	Non-oxidizing biocide treatment	-	-	-	-	**-**	2	Unlimited	
Mitsubishi Heavy Industries, Ltd.(Hybrid BWTS)	Filtration and electrochlorination	MEPC 56/23 ¶ 2.10MEPC 56/2/2 Annex 7 [GESAMP]MEPC 56/2	-	-	-	-	-	-	This system uses the "Marine-Growth-Prevention System." MEPC 55/2/15
Mitsui Engineering and Shipbuilding Co. Ltd. (FineBallast MF)	Filtration (pre-filtration and membrane filtration)	MEPC 61/2/3	-	-	-	**-**	-	-	
Mitsui Engineering and Shipbuilding Co. Ltd. (Special Pipe Hybrid BWMS Combined with PERACLEAN® Ocean (SPO-SYSTEM))	Shear, cavitation, and PERACLEAN® Ocean	Applicant states that Basic Approval of PERACLEAN® was granted at MEPC 54 (see entries for Hamann AG's SEDNA® system)	MEPC 61/2/10	Land (2008)	Imari City, Japan	-	-	-	It is assumed that Mitsui Engineering and Shipbuilding Co. Ltd. manufactures this system because: - The name of the system is similar to that of another Mitsui product, the "Special Pipe Hybrid BWMS" (or "SP-Hybrid BWMS Ozone Version; see MEPC 59/2/1 ¶ 3 - MEPC 61/2/10 Section 1.1 states that the SPO-SYSTEM "represents *one version* of SP-Hybrid BWMS" (emphasis added) - MEPC 61/2/10 was submitted to IMO by Japan, as were the applications for Basic and Final approval of Mitsui's SP-Hybrid BWMS Ozone Version
Mitsui Engineering and Shipbuilding Co. Ltd. (SP-Hybrid BWMS Ozone Version)	Hydrodynamic shear, cavitation, and ozonation	**October 2006** MEPC 55/23 ¶ 2.16 MEPC 55/2/16 Annex 5 [GESAMP] MEPC 55/2	MEPC 61/2/2 MEPC 59/24 ¶ 2.10 MEPC 59/2/16 Annex 4 [GESAMP] MEPC 59/2/1	Land (Feb-08) Sea (Jul-09)	JAMS	-	1	40-100	The name of this system was changed to "Special Pipe Hybrid Ballast Water Management System combined with Ozone treatment version (SP-Hybrid BWMS Ozone Verision);" see MEPC 61/2/2 ¶ 3. MEPC 53/2/16, MEPC 54/2/9, MEPC 55/2/15, MEPC 57/2/9

Supplier System	Process	G9 Active Substance Approval (Basic)[1]	G9 Active Substance Approval (Final)[1]	G8 System Approval[2]	Test Site	Type Approval	Units Installed[3]	Projected Production (Units/Year)[3]	Notes
NEI Treatment Systems LLC (Venturi Oxygen Stripping (VOS))	Deoxygenation and cavitation	N/A	N/A	-	NOAA	**11 October 2007** Liberia	6	200	MEPC 53/2/14, MEPC 53/2/16
NK-O3 (BlueBallast Ozone)	Ozonation	**July 2007** MEPC 56/23 ¶ 2.9 MEPC 56/2/2 Annex 6 [GESAMP] MEPC 55/2/27 MEPC 55/23 ¶ 2.16 MEPC 55/2/16 Annex 6 [GESAMP] MEPC 55/2/3	**July 2009** MEPC 59/24 ¶ 2.8.2 MEPC 59/2/16 Annex 6 [GESAMP] MEPC 59/2/3 MEPC 58/23 ¶ 2.11 MEPC 58/2/8 Annex 6 [GESAMP] MEPC 58/2/3	Land (2008) Sea (2008)	KOMERI	**24 November 2009** Korea MEPC 60/INF.14	4	400-700	NK-O3 is affiliated with Nutech O_3 (as listed in Lloyd's Register Reports). MEPC 53/2/14, MEPC 55/2/21, MEPC 57/2/9
Oceansaver AS (OceanSaver® BWMS)	Filtration, deoxygenation, and cavitation	**April 2008** MEPC 57/21 ¶ 2.17 MEPC 57/2/10 Annex 8 [GESAMP] MEPC 57/2/6	**October 2008** MEPC 58/23 ¶ 2.10 MEPC 58/2/8 Annex 4 [GESAMP] MEPC 58/2/1	Land (Nov-07) Sea (Sep-08)	NIVA	**17 April 2009** Norway MEPC 59/INF.17	6	>200	MEPC 53/2/16, MEPC 55/INF.3
OptiMarin (OptiMarin Ballast System)	Filtration and ultraviolet	N/A	N/A	Land (May-08) Sea (Jan-09)	NIVA	**12 November 2009** Norway	11	1000	MEPC 53/2/14, MEPC 53/2/16, MEPC 55/INF.3
Panasia Co Ltd Korea (GloEn Patrol™)	Filtration and ultraviolet	**April 2008** MEPC 57/21 ¶ 2.15 MEPC 57/2/10 Annex 6 [GESAMP] MEPC 57/2/4	**March 2010** MEPC 60/22 ¶ 2.7.1 MEPC 60/2/11 Annex 4 [GESAMP] MEPC 59/2/7	Land (Dec-08) Sea (Oct-09)	KORDI	**4 December 2009** Korea	2	1400	
Pinnacle Ozone Solutions	Filtration and ozonation	-	-	-	GSI	**-**	-	-	
Qingdao Headway Technology Co., Ltd. (OceanGuard™)	Filtration, electrolysis-electrochlorination, and ultrasound	**March 2010** MEPC 60/22 ¶ 2.4.7 MEPC 60/2/16 Annex 6 [GESAMP] MEPC 60/2/8	MEPC 61/2/7	Land (Oct-09) Sea (Early-10)	NIVA	-	1	2000	This system uses "Advanced Electrocatalysis Enhanced by Ultrasonic Technology (EUT)."

Supplier System	Process	G9 Active Substance Approval (Basic)[1]	G9 Active Substance Approval (Final)[1]	G8 System Approval[2]	Test Site	Type Approval	Units Installed[3]	Projected Production (Units/Year)[3]	Notes
Qwater	Filtration and ultrasound	-	-	-	-	-	0	-	MEPC 53/2/16
Resource Ballast Technologies (Pty) Ltd.(Resource Ballast Technologies System / Unitor BWTS)	Cavitation, ozonation, electrochlorination, and filtration	**April 2008**MEPC 57/21 ¶ 2.14MEPC 57/2/10 Annex 5 [GESAMP]MEPC 56/2/3	**March 2010**MEPC 60/22 ¶ 2.7.2MEPC 60/2/11 Annex 7 [GESAMP]MEPC 59/2/10	Land (2010)Sea (2010)	Cape Town	-	4	2000+	MEPC 53/2/16
RWO GmbH Marine Water Technology, Veolia Water Solutions & Technologies (CleanBallast!)	Filtration, electrolysis-electrochlorination, and advanced oxidation	**October 2006** MEPC 55/23 ¶ 2.16 MEPC 55/2/16 Annex 7 [GESAMP] MEPC 55/2/4	**July 2009** MEPC 59/24 ¶ 2.8.1 MEPC 59/2/16 Annex 5 [GESAMP] MEPC 59/2 MEPC 57/21 ¶ 2.12 MEPC 57/2/13 MEPC 57/2 Annex 6 [GESAMP] MEPC 57/2/3	Land (Sep-07) Land (Nov-08) Sea (Jan-10)	Bremen 2007 NIVA 2008	-	16	Unlimited	This system uses EctoSys®. MEPC 53/2/11 Annex 1, MEPC 53/2/16, MEPC 54/INF.6, MEPC 55/2/17 Annex 1, MEPC 56/2/10, MEPC 57/2/9
Sea Knight Corporation	Vacuum de-oxygenation and bio-remediation	-	-	-	Virginia	-	0	Unlimited	
Severn Trent De Nora (BalPure®)	Filtration and electrolysis-electrochlorination	**March 2010** MEPC 60/22 ¶ 2.4.8 MEPC 60/2/16 Annex 7 [GESAMP] MEPC 60/2/9	MEPC 61/2/9	Land (Jul-09)	NIOZ	-	2	100	This system is installed on board SeaRiver Maritime's S/R AMERICAN PROGRESS as a part of the USCG STEP (74 FR 38666). MEPC 53/2/16
Siemens (SiCURE™ BWMS)	Filtration and electrochlorination	**March 2010** MEPC 60/22 ¶ 2.4.1 MEPC 60/2/11 Annex 6 [GESAMP] MEPC 59/2/11	-	-	GSI and MERC	-	-	-	This system uses Siemens' Chloropac® electrochlorination technology.

Supplier System	Process	G9 Active Substance Approval (Basic)[1]	G9 Active Substance Approval (Final)[1]	G8 System Approval[2]	Test Site	Type Approval	Units Installed[3]	Projected Production (Units/Year)[3]	Notes
Sunrui Corrosion and Fouling Control Company (BalClor™ BWMS)	Filtration and electrolysis-electrochlorination	**March 2010** MEPC 60/22 ¶ 2.4.2 MEPC 60/2/12 Annex 6 [GESAMP] MEPC 60/2/3	MEPC 61/2/4	Land (Late-09) Sea (Late-09)	Qingdao, China	-	-	-	The name of this system was changed from "Sunrui BWMS" to "BalClor™ BWMS;" see MEPC 61/2/4 ¶ 3.
Techcross (Electro-Clean System (ECS))	Electrolysis-electrochlorination	**March 2006** MEPC 54/21 ¶ 2.8 MEPC 54/2/12 Annex 6 [GESAMP] MEPC 54/2/3	**October 2008** MEPC 58/23 ¶ 2.8 MEPC 58/2/7, Annex 7 [GESAMP] MEPC 58/2 MEPC 57/21 ¶ 2.9 MEPC 57/2 Annex 4 [GESAMP] MEPC 57/2/1	August 2007	KORDI	**31 December 2008** Korea MEPC 59/INF.6	13	1200	Possibly MEPC 53/2/31. MEPC 55/2/21, MEPC 57/2/9. Explosion-proof type approval certificate issued September 2009 (Lloyd's, 2010).
Techwin Eco Co., Ltd. (TWECO) (Purimar™)	Filtration and electrolysis-electrochlorination	MEPC 61/2	**-**	-	-	**-**	-	-	
Vitamar, LLC (Seakleen™)	Menadione / Vitamin K (Seakleen™)	-	-	-	-	-	0	-	Former supplier: Hyde Marine; Lamor Corporation, LLC.

Additional Notes:
Data sources for this spreadsheet include Ballast Water Treatment Technology - Current Status, Lloyd's Register Review (September 2008), Ballast Water Treatment Technology - Current Status, Lloyd's Register Review (February 2010), and MEPC Reports. System names in this table and elsewhere in this paper may be subject to copyright or trademark protection by their owners.
1 Where applicable. Systems that employ an "Active Substance," defined by BW Treaty Regulation A-1(7) as "a substance or organism, including a virus or a fungus that has a general or specific action on or against harmful aquatic organisms and pathogens," are assessed according to the MO G9 Procedure for Approval of Ballast Water Management Systems that make use of Active Substances (International Maritime Organization, 2008a).
2 The ballast water treatment system testing procedure is outlined in the IMO's G8 Guidelines (International Maritime Organization, 2008b).
3 Data on units installed and on projected production was provided by vendors to Lloyd's Register Review during Lloyd's research of ballast water treatment systems. The numbers listed here are based solely on this vendor-supplied information as reported by Lloyd's (see Ballast Water Treatment Technology - Current Status, Lloyd's Register Review (February 2010).
4 Per Lloyd's Register Review (Ballast Water Treatment Technology - Current Status (September 2008)), testing may not strictly meet IMO standards.

Table 6 Acronyms and Abbreviations used in Table 5.

BWMS	Ballast Water Management System
BWTS	Ballast Water Treatment System
CBL	Chesapeake Biological Laboratory
IMO	International Maritime Organization
JAMS	Japan Association of Marine Safety
KORDI	Korean Oceanic Research and Development Institute
MEPC	Marine Environment Protection Committee (IMO)
MLML	Moss Landing Marine Laboratories
N/A	Not Applicable or Available
NIOZ	Royal Netherlands Institute for Sea Research
NIVA	Norwegian Institute for Water Research
NOAA	National Oceanic and Atmospheric Administration
SIO	Scripps Institute of Oceanography
STEP	Shipboard Technology Evaluation Program
USNRL	United States Naval Research Laboratory

4.4. Implications of Sampling Protocols for Data Quality

To date, efforts to quantify the efficacy of ballast water treatment systems, either in land-base or shipboard tests have been hampered by a range of methodological and practical constraints. The BW Treaty's G8 Guidelines were developed through a process of best professional judgment and policy negotiations. Significant aspects, such as guidance on how to analyze samples for the different types of organisms are treated very loosely in the G8 Guidelines because it was not possible to come to agreement on such complicated issues in the short timeframe allowed. Other sections, such as those on challenge water conditions and sample sizes, are quite detailed, but were not formally validated prior to their use by different entities. The consequence has been the evolution of a mosaic of procedures, developed individually by each of the facilities conducting testing internationally, within the general conceptual framework of the G8 Guidelines, but differing substantially in specific details. Within the last several months the various test facilities have begun to discuss approaches to achieve "harmonization" of test methods.

In the U.S., efforts to develop standard protocols for testing the efficacy of ballast water treatment systems were begun by EPA and the USCG under the auspices of the EPA Environmental Technology Verification (ETV) Program in 2002. An early version of the draft ETV protocol was used by the U.S. as the basis for a submission to MEPC during negotiation of the G8 Guidelines, and much of the ETV conceptual approach was incorporated into the G8 Guidelines. However, as the ETV process continued to develop the protocols, and then validate their practicability and appropriateness, the ETV protocols evolved substantially (Lemieux et al., 2008b, Lemieux et al., 2009), and the version now nearing finalization (U.S., EPA, 2010) differs significantly from the version under discussion at the time the G8 Guidelines were being developed. Unlike the ETV protocols, however, the G8 Guidelines were never subjected to rigorous validation.

Validation of the ETV protocols has revealed that the initial approaches to sampling design had substantial limitations. In particular, the early ETV protocols, and the current G8 Guidelines, called for collecting three 1m^3 samples of water to quantify concentrations of living organisms larger than 50 um following treatment. For the BW Treaty Regulation D-2 standard of less than 10 organisms in this size group, this means that quantification would have to be able to detect the presence of 10 organisms, each as small as 50 um in diameter, in one cubic meter of water. In practice, this involves concentrating the organisms in the cubic meter samples down to a liter, or in some cases, several hundred milliliters. These concentrated samples are then examined, either in their entirety, or by sub-sampling, and the number of living organisms is counted.

Even if the entire concentrated sample is enumerated, counting 10 organisms as small as 50 um in a liter with adequate precision is a significant challenge. Five to ten cubic meters of sample, concentrated to a liter would provide a much better basis for counting. Sub-sampling would greatly increase the original sample volume required.
NRL, in validating the ETV protocols, determined that for the circumstances at Key West, FL, where the NRL test facility is located, 20 1 ml subsamples was about the maximum that could be processed within the allowable time before sample degradation introduced significant artifacts (e.g., increased organism mortality in the concentrated sample).

Enumeration of the organisms from these samples is represented by the Poisson distribution, and therefore the cumulative or total count is the key test statistic (Lemieux et al., 2008). Further, a chi-square transformation can be utilized to approximate the confidence intervals. Assuming, for organisms $\geq$ 50 μm, that the desired minimum precision is that the upper bound of the chi-square statistic should not exceed twice the observed mean (this corresponds to a coefficient of variation of 40%), a count of 6 organisms is required. The volume required to successfully count 6 organisms is dependent on the whole water sample volume, concentration factor, number of sub-samples counted, and the target concentration. For enumeration using 20 one ml subsamples, statistical analysis indicated that 30 m^3 must be sampled to enumerate 10 organisms/m^3, with the desired level of precision.

The complexities associated with minimum sample volumes raise additional important issues. First, counts of less than 10 organisms as small as 50 um in size per cubic meter are inherently susceptible to error. To date, none of the test reports available to the Coast Guard and EPA have contained QA/QC validation that the counts were made with necessary precision and repeatability. In validating the ETV protocols, NRL validated their measurement precision using different concentrations of various diameter microbeads. Second, samples begin to degrade very quickly, and all enumeration must be completed within a narrow window, and this window is to a great degree dependent on time and place and holding conditions. As with measurement precision, the test reports available to the Coast Guard and EPA do not contain QA/QC documentation of the safe period for sample processing and analysis or that this safe period limitation was met.

5. Conclusion – How this Report could be used

In its 2008 Fact Sheet to the VGP (EPA, 2008a), EPA noted that the Agency "will evaluate the availability of technologies that are able to meet appropriate living organism limitations. Once technologies are commercially available and economically achievable, EPA would require that these standards be met as a BAT effluent limit for ballast water discharges under subsequent iterations of this permit." Under § 402(b)(1)(B) of the CWA, NPDES permits are issued for fixed terms that may not exceed five years and the existing VGP will expire on December 19, 2013. The SAB's response to the charge will better inform EPA as to the status of ballast water treatment systems as the Agency develops new technology-based effluent limits and conditions for the next VGP.

As a co-regulator, the US Coast Guard is supporting EPA in this effort. Additionally, the SAB's findings may also help inform the Coast Guard in their future evaluations of technological availability. We are not asking the committee to propose or strongly support any specific technology or treatment train, rather, we are asking for advice on the state and efficacy of ballast water treatment technology today and where that is likely to go in the near term. This information will assist regulatory agencies in moving toward a strong US federal ballast water management program which accurately captures the current state of ballast water technologies.

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Appendix I – Science Advisory Board Charge

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

OFFICE OF
WATER

July 1, 2010

MEMORANDUM

SUBJECT: Science Advisory Board Review of the Availability and Efficacy of Ballast Water Treatment Technology for EPA's Office of Water and the United States Coast Guard

FROM: Linda Boornazian, Director
Water Permits Division
Office of Water

TO: Vanessa Vu, Director
Science Advisory Board Staff Office

This memorandum provides an introduction, background information, and specific charge questions to the Science Advisory Board (SAB) for their review of the status of ballast water treatment technology. To assist the SAB in their efforts, a member of my staff, in collaboration with other EPA and Coast Guard colleagues, has prepared a white paper titled "Availability and Efficacy of Ballast Water Treatment Technology: Background and Issue Paper" (hereinafter the "White Paper"). This paper provides additional background information and introduces the numerous documents we have provided to the SAB to assist in your analyses.

Background

Ballast water is typically drawn in from surrounding ambient water and used to assist with vessel draft, buoyancy, and stability. Almost all large vessels have ballast tanks dedicated to this purpose; some vessels may also ballast empty cargo holds. The ballast water discharge rate and constituent concentrations of ballast water from vessels will vary by vessel type, ballast tank capacity, and type of deballasting equipment. Under current U.S. regulation and permitting

requirements (discussed in greater detail in the White Paper), there are existing best management practices to reduce the potential impacts of ballast water discharges. These include ballast water exchange and salt water flushing (collectively referred to as BWE).

While useful in reducing the presence of potentially invasive organisms in ballast water, BWE can have variable effectiveness and may not always be feasible due to vessel safety concerns. In order to make progress beyond use of BWE, establishing a standard for the concentration of living organisms in ballast water that can be discharged is necessary. The United States Environmental Protection Agency (EPA) and the United States Coast Guard (USCG) both desire a stronger federal ballast water management program.

To help develop the next Clean Water Act Vessel General Permit (VGP), EPA needs an objective evaluation of the status and efficacy of ballast water treatment technologies and systems that are in existence or in the development process. A second major scientific question for regulatory agencies is to better understand and relate the concentration of living organisms in ballast water discharges to the probability of introduced organisms successfully establishing populations in U.S. waters. Given the complexity of the issues, EPA's Office of Water is seeking advice from the Science Advisory Board (SAB) on the first issue and the National Academy of Sciences' National Research Council (NRC) on the second issue. In Particular, EPA is seeking advice from the SAB regarding the availability and efficacy of ballast water treatment systems in neutralizing (killing) living organisms that might be discharged from ballast water tanks. For the other NRC study, EPA has requested that the NRC broadly assess and make recommendations about various approaches for assessing the risk of establishment of new aquatic non-indigenous species from ballast water discharges (see attachment 2 of the White Paper for the NRC charge).

Specific Charge in Evaluating the Efficacy of Ballast Water Treatment Technology

OW is seeking SAB advice in the following four general categories:

1. **<u>Performance of shipboard systems with available effluent testing data</u>[25]**

    1a. For the shipboard systems with available test data, which have been evaluated with sufficient rigor to permit a credible assessment of performance capabilities in terms of effluent concentrations achieved (living organisms/unit of ballast water discharged or other metric)?

    1b. For those systems identified in (1a), what are the discharge standards that the available data credibly demonstrate can be reliably achieved (e.g., any or all of the standards shown in Table 1 of the White Paper? Furthermore, do data indicate that certain systems (as tested) will not be able to reliably reach any or all of the discharge standards shown in that table?

[25] EPA and the US Coast Guard have provided data they currently have to the panel on the attached CD. Where feasible, the panel is encouraged to find additional data if they have appropriate avenues to obtain those data.

1c. For those systems identified in (1a), if any of the system tests detected “no living organisms” in any or all of their replicates, is it reasonable to assume the systems are able to reliably meet or closely approach a “no living organism” standard or other standards identified in Table 1 of the White Paper, based on their engineering design and treatment processes?

2. Potential performance of shipboard systems without reliable testing data

2. Based on engineering design and treatment processes used, and shipboard conditions/constraints, what types of ballast water treatment systems (which may include any or all of the systems listed in Table 4 of the White Paper) can reasonably be expected to reliably achieve any of the standards shown in Table 1 of the White Paper, and if so, by what dates? Based on engineering design and treatment processes used, are there systems which conceptually would have difficulty meeting any or all of the discharge standards in Table 1 of the White Paper?

3. System Development

3a. For those systems identified in questions 1a and 2, are there reasonable changes or additions to their treatment processes which can be made to the systems to improve performance?

3b. What are the principal technological constraints or other impediments to the development of ballast water treatment technologies for use onboard vessels to reliably meet any or all of the discharge standards presented in Table 1 of the White Paper and what recommendations does the SAB have for addressing these impediments/constraints? Are these impediments more significant for certain size classes or types of organisms (e.g., zooplankton versus viruses)? Can currently available treatment processes reliably achieve sterilization (no living organisms or viable viruses) of ballast water onboard vessels or, at a minimum, achieve zero or near zero discharge for certain organism size classes or types?

4. Development of Reliable Information

4. What are the principal limitations of the available studies and reports on the status of ballast water treatment technologies and system performance and how can these limitations be overcome or corrected in future assessments of the availability of technology for treating ballast water onboard vessels?

Background Reading Materials

A more in depth introduction to these issues can be found in the attached White Paper, for which we have included both a hard copy and an electronic copy on the attached CD. The documents on the CD are divided into three groups. The first set of documents on that CD are summary reports produced by parties evaluating the availability of existing ballast water treatment systems or reports evaluating their potential efficacy. The second set of documents contains additional available test data and engineering information for specific ballast water treatment systems. The third set of documents primarily consist of International Maritime Organization papers and submissions, and were provided to serve as a reference library for the committee should the committee therein useful. Most of those documents have been prepared as reports for IMO as part of the "G9" review process (discussed in greater detail in White Paper). There is also an index file on the CD, which lists all of the document names and contains hyperlinks to the location of each file on the CD. Additionally, we have created an on-line docket which will contain all of the documents found on this CD: it is docket number EPA-HQ-OW-2010-0582 and can be accessed at www.regulations.gov.

Thank you for considering these important issues in your review. Your work will prove valuable as we move forward with federal ballast water regulation.

Attachments:

1. June, 2010 White Paper: Albert, R., Everett, R., Lishman, J., and Smith, D. (2010) Availability and Efficacy of Ballast Water Treatment Technology: Background and Issue Paper. Paper prepared to assist the Science Advisory Board Review of the availability and efficacy of ballast water treatment technology.
2. Compact Disc containing all documents referenced in Appendix IV of the above White Paper.

Appendix II. National Academy of Sciences Charge

THE NATIONAL ACADEMIES

Advisers to the Nation on Science, Engineering, and Medicine

National Academy of Sciences
National Academy of Engineering
Institute of Medicine
National Research Council

Water Science and Technology Board
Division on Earth and Life Sciences
May 2010

Committee on Assessing Numeric Limits for Living Organisms in Ballast Water

EPA and the U.S. Coast Guard have requested the NRC to conduct a study that will significantly inform their efforts to derive environmentally protective numeric ballast water discharge limits in the next Vessel General Permit. The study will take into account estuarine and freshwater systems, including the Great Lakes and other inland navigable waters, as well as the waters of the three-mile territorial sea, considering what implications their differing environmental and ecological conditions might have for the development of allowable concentrations of living organisms in discharged ballast water. Specifics tasks are outlined below.

1. Evaluate the state of the science of various approaches that assess the risk of establishment of aquatic nonindigenous species (NIS) given certain concentrations of living organisms in ballast water discharges.

- What are the advantages and disadvantages of the available approaches?
- Identify and discuss the merits and practical utility of other additional approaches of which the NRC is aware.
- How can the various approaches be combined or synthesized to form a model or otherwise more powerful approach?
- What are the data gaps or other shortcomings of the various approaches and how can they be addressed within the near and long term?
- Can a "natural invasion rate" (invasion rates based on historic invasion rates), or other "natural" baselines, be reliably established, and if so, how? What utility might such baselines have in informing EPA's derivation of allowable numeric limits for living organisms in ballast water discharges? Can such baselines be established on a national basis, or would this need to be done on a regional or ecosystem basis?

2. Recommend how these approaches can be used by regulatory agencies to best inform risk management decisions on the allowable concentrations of living organisms in discharged ballast water in order to safeguard against the establishment of new aquatic NIS and to protect and preserve existing indigenous populations of fish, shellfish, and wildlife and other beneficial uses of the nation's waters.

3. Evaluate the risk of successful establishment of new aquatic NIS associated with a variety of ballast water discharge limits that have been used or suggested by the international community and/or domestic regulatory agencies.

The study is sponsored by the U.S. Environmental Protection Agency and the U. S. Coast Guard. The study director is Laura Ehlers (lehlers@nas.edu), WSTB senior staff officer. An expert committee of 9 members will meet three times over a 14-month period and produce a report in mid-2011; the members of this multidisciplinary committee are:

James T. Carlton, *Chair*, Williams College, Mystic, Connecticut
Gregory M. Ruiz, *Vice-chair*, Smithsonian Environmental Research Center, Edgewater, Maryland
James (Jeb) E. Byers, University of Georgia, Athens
Allegra Cangelosi, Northeast-Midwest Institute, Washington, DC
Fred C. Dobbs, Old Dominion University, Norfolk, Virginia
Edwin D. Grosholz, University of California, Davis
Brian Leung, McGill University, Montreal, Quebec
Hugh J. MacIsaac, University of Windsor, Windsor, Ontario
Marjorie J. Wonham, Quest University, Squamish, British Columbia

Appendix III. List of Acronyms Used in this Paper

ABS	American Bureau of Shipping
ANS	Aquatic nuisance species
BA	Basic Approval
BAT	Best available technology economically achievable
BMP	Best management practice
BOG	Blue Ocean Guardian
BW	Ballast water
BWE	Ballast Water Exchange
BWM	Ballast Water Management
BWT	Ballast Water Treatment
BWTS	Ballast Water Treatment System
CFR	Code of Federal Regulations
COSCO	China Ocean Shipping (Group) Company
CSLC	California State Lands Commission
CWA	Clean Water Act
ECS	Elector-Cleen™ (Electro-Clean) System
EEZ	Exclusive Economic Zone
EPA	Environmental Protection Agency
ETV	Environmental Technology Verification Program
EUT	Advanced Electrocatalysis Enhanced by Ultrasonic Technology
FA	Final Approval
GESAMP	Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection
GSI	Great Ships Initiative
HHI	Hyundai Heavy Industries
IMO	International Maritime Organization
JAMS	Japan Association of Marine Safety
KOMERI	Korean Marine Equipment Research Institute
KORDI	Korean Oceanic Research and Development Institute
KS	Kwang San
LLC	Limited Liability Company
MEPC	Marine Environment Protection Committee
MERC	Maritime Environmental Resource Center
MLML	Moss Landing Marine Laboratories
N/A	Not applicable or available
NANPCA	Non-indigenous Aquatic Nuisance Prevention and Control Act
NIOZ	Royal Netherlands Institute for Sea Research
NIS	Non-indigenous species
NISA	National Invasive Species Act
NIVA	Norwegian Institute for Water Research
NOAA	National Oceanic and Atmospheric Administration
NOBOB	No Ballast On Board
NPDES	National Pollutant Discharge Elimination System
NPRM	Notice of Proposed Rulemaking
NRC	National Research Council
NRL	Naval Research Laboratory
OBS	OptiMarin Ballast System

POC	Particulate organic carbon
QA/QC	Quality assurance/quality control
SAB	Science Advisory Board
SIO	Scripps Institute of Oceanography
SP	Special pipe
STEP	Ship Technology Evaluation Program
TA	Type Approval
TG	Toagosei Group
TRO	Total residual oxidant
TSS	Total suspended solids
TWECO	Techwin Eco Company
ULCC	Ultra large crue carrier
UN	United Nations
US	Ultrasonic
USC	United States Code
USCG	United States Coast Guard
UV	Ultraviolet
VGP	Vessel General Permit
VOS	Venture Oxygen Stripping
WI DNR	Wisconsin Department of Natural Resources

Appendix IV. Table of Contents for all documents provided to the Committee.

Note that hyperlinks in this table to documents link to other files contained on a CD provided to the SAB committee. If this white paper is viewed from that CD, hyperlinks will open the documents. These documents have also been added to the docket number EPA-HQ-OW-2010-0582 and can be accessed at www.regulations.gov.

System	Title	Date	File name
Group 1: 3rd Party Reports			
General	Ballast Water Treatment Technology: Current Status	Feb-10	0210LloydsReport
General	2009 Assessment of the Efficacy, Availability and Environmental Impacts of Ballast Water Treatment Systems for Use in California Waters	Jan-09	2009CSLCTechReportFinal
General	October 2010 Update: Ballast Water Treatment Technologies for Use in California Waters	10/15/2009	CSLCTechUpdate2009_final
General	Density Matters: Review of Approaches to Setting Organism-Based Ballast Water Discharge Standards	2010	Lee_Density Matters- Excerpts for SAB
General	International Convention for the Control and Management of Ships' Ballast Water and Sediments, 2004 - List of ballast water management systems that make use of Active Substances which received Basic and Final Approvals	9/24/2009	BWM.2-Circ.23.pdf
General	Ballast Water Treatment Advisory	6/8/2010	ABS_BWMAdvisoryNotice.pdf
Group 2: Direct Data Reports on Separate BWMS			
Ecochlor® Ballast Water Treatment System	STEP 2006 Application Form - Section 4.0: Proof of Ballast Water Treatment Performance	2006	Final - STEP Section 4
Ecochlor® Ballast Water Treatment System	Final report of the land-based testing of the Ecochlor®-system, for Type Approval according to regulation-D2 and the relevant IMO guideline (April – July 2008)	Feb-09	G8-Eco-_report_BSH-v8-final
Ecochlor® Ballast Water Treatment System	Final Environmental Assessment Review of the Application by Atlantic Container Lines for Acceptance of the Vessel M/V *Atlantic Compass* and the Ecochlor™ Inc. Technology into the USCG Shipboard Technology Evaluation (STEP) Program	Aug-08	USCG-2007-0042-0010.1
Electro-Clean Ballast Water Management System	Development of technologies on test facility and procedures for the land-based test as a type approval test at ballast water treatment system	2008	Electroclean barge

System	Title	Date	File name
Electro-Clean™ System	Information on the Type Approval Certificate of the Electro-Clean™ System (ECS)	2/20/09	59-INF.6_Electroclean-TypeApp-ROK
GloEn-Patrol™ Ballast Water Management System	Type Approval Certificate of Ballast Water Management System	12/4/09	GloEn-Patrol Type Approval Certificate
Greenship's Ballast Water Management System	Landbased Test Report - Test Cycle Summary	2007	Landb_Test_Rep_Summ_07_07
Hyde GUARDIAN Ballast Water Treatment System	Environmental Acceptability Evaluation of the Hyde GUARDIAN Ballast Water Treatment System as Part of the Type Approval Process	4/20/2009	environmental_acceptability_evaluation
Hyde GUARDIAN Ballast Water Treatment System	Final report of the land-based testing of the Hyde-Guardian™ -System, for Type Approval according to the Regulation D-2 and the relevant IMO Guideline (April - July 2008)	Jan-09	G8-HM-final report MCA
Hyde GUARDIAN Ballast Water Treatment System	Type Approval Certificate of Ballast Management System	4/29/2009	hyde_mca_cert
Hyde GUARDIAN Ballast Water Treatment System	Shipboard Trials of Hyde "Guardian" System in Caribbean Sea and Western Pacific Ocean, April 5th - October 7th, 2008	Apr-09	hyde_shipboard_tests
Hyde GUARDIAN Ballast Water Treatment System	Type Approval of the Hyde GUARDIAN™ Ballast Water Management System	5/7/2009	59-INF20_TypeApp-UK
OceanSaver® Ballast Water Management System	Det Norske Veritas Type Approval Certificate	4/8/2009	Oceansaver type approval certificate
OceanSaver® Ballast Water Management System	Type Approval Certificate of the OceanSaver ® BWMS	4/17/2009	Nor-OceanSaver
OceanSaver® Ballast Water Management System	Information on the Type Approval Certificate of the OceanSaver® Ballast Water Management System	5/6/2009	59-INF17_OceanSaver-TypeApp-Nor
OptiMarin Ballast System	Det Norske Veritas Type Approval Certificate	11/12/2009	Optmarin type approval certificate Z3_600_8349_20091112_133619
Peraclean	Toxic Shock as New Ballast Water Treatment Fails Test	2/9/2010	lloyds 2010 peraclean article
SEDNA® ballast water treatment system using PERACLEAN® Ocean	Effective Protection Against "Stowaways": Ballast Water Management System of Hamann and Evonik Receives Final Approval	6/11/2008	PeraClean-TypeApproval_PR

System	Title	Date	File name
SEDNA®-System	Final report of the land-based and shipboard testing of the SEDNA®-system	Mar-08	SEDNA Type Appr Test results.nioz
SEDNA®-System	Summary of Additional Provisions of the Type Approval Certificate of Ballast Water Management System SEDNA 250 of Hamann AG	Aug-08	Type Approval Additional Provisions HAMANN
SEDNA ® 250	Type Approval Certificate of Ballast Water Management System	8/16/2008	Ger Sedna
PureBallast 250-2500	Det Norske Veritas Type Approval Certificate	6/27/2008	PureBallast Type Approval Certificate
Siemens SICURE Ballast Water Management System	A Great Lake Relevancy Preamble to the GSI Report on Land-Based Testing Outcomes for the Siemens SICURE Ballast Water Management System	4/28/2010	GLPreamble
Siemens SICURE Ballast Water Management System	Report of the Land-Based Freshwater Testing of the Siemens SiCURE Ballast Water Management System	5/15/2010	GSI-LB-F-A-1
NEI Venturi Oxygen Stripping (VOS)	Application for Type Approval Certification: NEI Treatment Systems' Venturi Oxygen Stripping Ballast Water Management System.	Mar-07	VOS Application for Type Approval Certification
NEI Venturi Oxygen Stripping (VOS)	Short-term Toxicity Testing of a De-oxygenation Ballast Water Treatment to Receiving Water Organisms. Final Report.	8/29/2008	Short-term Acute Toxicity Testing
NEI Venturi Oxygen Stripping (VOS)	Short-term Chronic Toxicity Testing of a De-oxygenation Ballast Water Treatment to Receiving Water Organisms. Final Report.	3/27/2009	Short-term Chronic Toxicity Testing
NEI Venturi Oxygen Stripping (VOS)	STEP 2006 Application Form.	Mar-06	STEP Final Version 6-23-09
NEI Venturi Oxygen Stripping (VOS)	Evaluations of a Ballast Water Treatment to Stop Invasive Species and Tank Corrosion.	2005	Tamburri SNAME 2005 D09
NEI Venturi Oxygen Stripping (VOS)	Type Approval Certificate of Ballast Water Management System; Ballast Water Management System Type Approval Compliance Certificate	7/6/2009; 7/8/2007; 1/19/2010	NEI IMO BWM TYPE APPROVAL CERTIFICATE
Severn Trent De Nora (BalPure)	Washington State Dept. of Fish and Wildlife Application Package Ballast Water Treatment System	8/8/2005	BWT System Application Package 8-8-05
Severn Trent De Nora (BalPure)	Marrowstone Sodium Hypochlorite Mesocosm September 2004	Sep-04	Marrowstone Sodium Hypochlorite Mesocosm September 2004
Severn Trent De Nora (BalPure)	Environmental Assessment Review of the Application for Acceptance of the SeaRiver Maritime Inc. *S/R American Progress* and Severn Trent de Nora BalPure™ System into the Shipboard Technology Evaluation Program (STEP)	Feb-09	USCG-2008-0126-0007.1

System	Title	Date	File name
Group 3: G9 Files			
Alfa Laval Ballast Water Management System (PureBallast)	Basic Approval of Active Substances used by PureBallast management system	4/21/2006	55-2-5_PureBal-Swe-Basic
Alfa Laval Ballast Water Management System (PureBallast)	Application for Final Approval of a ballast water management system using Active Substances	12/15/2006	56-2-1_PureBal-Nor-Final
AquaStar Ballast Water Management System	Application for Basic Approval of AquaStar Ballast Water Management System	3/18/2010	61-2-1_AquaStar-Jap-Baasic
AquaTriComb Ballast™ Water Treatment System	Application for Basic Approval of the AquaTriComb Ballast Water Treatment System	12/16/2008	59-2-8_AquaTriComb-Ger-Basic
AquaTriComb Ballast™ Water Treatment System	Application for Basic Approval of the AquaTriComb™ Ballast Water Treatment System Corrigendum	6/29/2009	MEPC 59-2-8-Corr.1
"ARA Ballast" Ballast Water Management System (formerly Blue Ocean Guardian BWMS)	Application for Final Approval of "ARA Ballast" Ballast Water Management System	3/23/2010	61-2-5_ARA-ROK-Final
BalPure®	Application for Basic Approval of the Severn Trent DeNora BalPure® Ballast Water Management System	8/28/2009	60-2-9_BalPure-Ger-Basic
BalPure®	Application for Final Approval of the Severn Trent DeNora BalPure® Ballast Water Management System	3/28/2010	61-2-9_BalPure-Ger-Final
Blue Ocean Guardian (BOG) Ballast Water Management System	Application for Basic Approval of Blue Ocean Guardian (BOG) Ballast Water Management System	8/24/2009	60-2-5_BlueOceanGuardian-ROK-Basic
Blue Ocean Shield Ballast Water Management System	Application for Basic Approval of the Blue Ocean Shield Ballast Water Management System	12/5/2008	59-2-2_BlueOceanShield-China_basic
BlueSeas Ballast Water Management System	Application for Basic Approval of the BlueSeas Ballast Water Management System	3/31/2010	61-2-12_BlueSeas-Sing-Basic
DESMI Ocean Guard Ballast Water Management System	Application for Basic Approval of the DESMI Ocean Guard Ballast Water Management System	8/19/2009	60-2-4_OceanGuard-Den-Basic
EcoBallast	Application for Basic Approval of the HHI Ballast Water Management System (EcoBallast)	12/9/2008	59-2-4_HHI-EcoBallast-ROK-Basic
EcoBallast	Application for Final Approval of HHI Ballast Water Management System "EcoBallast"	8/20/2009	60-2-1_EcoBallast-ROK-Final

System	Title	Date	File name
Ecochlor® Ballast Water Treatment System	Application for Basic Approval of the Ecochlor® Ballast Water Treatment System	3/20/2008	58-2-2 Ecochlor-Ger-Basic
Ecochlor® Ballast Water Treatment System	Application for Final Approval of the Ecochlor® Ballast Water Management System	12/16/2008	59-2-9 EcoChlor-Ger-Final
Ecochlor® Ballast Water Treatment System	Application for Final Approval of the Ecochlor® Ballast Water Management System	3/28/2010	61-2-8 EcoChlor-Ger-Final2
EctoSys™	A Swedish Disinfection System	1/13/2006	54-INF-6 EctoSys-Swe-Basic
EctoSys™	Basic Approval of Active Substances used by EctoSys™ electrochemical system	4/21/2006	55-2-4 EctoSys-Swe-Basic
ERMA FIRST	Application for Basic Approval of the ERMA FIRST Ballast Water Management System	3/29/2010	61-2-11 ERMA FIRST-GR-Basic
CleanBallast!	Comments on the report of the fourth meeting of the GESAMP-BWWG	2/4/2008	57-2-13 CleanBallast-Ger-Rebut
CleanBallast!	Application for Final Approval of a ballast water management system using Active Substances	9/7/2007	57-2-3 CleanBallast-Ger-Final-1
CleanBallast!	Application for Final Approval of the RWO Ballast Water Management System (CleanBallast)	11/28/2008	59-2 CleanBallast-Ger-Final-2
Electro-Clean Ballast Water Management System	Application for Basic Approval of Active Substances used by Electro-Clean (Electrolytic Disinfection) Ballast Water Management System	12/16/2005	54-2-3 ElectroClean-ROK-Basic
Electro-Clean Ballast Water Management System	Application for Final Approval of a ballast water management system using Active Substances (Electro-Clean Electrolytic Disinfection)	9/7/2007	57-2-1 ElectroClean-ROK-Final
Electro-Clean Ballast Water Management System	Application for Final Approval of a ballast water management system using Active Substances (Electro-Clean Electrolytic Disinfection). Corrigendum	3/12/2008	57-2-1-Corr.1
Electro-Clean Ballast Water Management System	Application for Final Approval of the Electro-Clean System (ECS)	3/20/2008	58-2 ElectroClean-ROK-Final
En-Ballast	Application for Basic Approval of Kwang San Co., Ltd. (KS) Ballast Water Management System "En-Ballast"	8/25/2009	60-2-7 EnBallast-ROK-Basic
GloEn-Patrol™ Ballast Water Management System	Basic Approval of Active Substance used by GloEn-Patrol™	9/7/2007	57-2-4 GloEnPatrol-ROK-Basic
GloEn-Patrol™ Ballast Water Management System	Application for Final Approval of the GloEn-Patrol™ Ballast Water Treatment System	12/16/2008	59-2-7 GloEnpatrol-ROK-Final

System	Title	Date	File name
Greenship's Ballast Water Management System	Application for Basic Approval of a combined ballast water management system consisting of sediment removal and an electrolytic process using seawater to produce Active Substances (Greenship Ltd)	12/20/2007	57-2-7 Greenship-Neth-Basic
Greenship Sedinox Ballast Water Management System	Application for Final Approval of the Greenship Sedinox Ballast Water Management System	12/12/2008	MEPC 59-2-6 Greenship-Neth-Final
HiBallast	Application for Basic Approval of Hyundai Heavy Industries Co., Ltd. (HHI) Ballast Water Management System (HiBallast)	8/24/2009	60-2-6 HiBallast-ROK-Basic
Hitachi Ballast Water Purification System (ClearBallast)	Application for Basic Approval of Active Substances used by Hitachi Ballast Water Purification System (ClearBallast)	9/7/2007	57-2-2 ClearBallast-Jap Basic
Hitachi Ballast Water Purification System (ClearBallast)	Application for Final Approval of the Hitachi Ballast Water Purification System (ClearBallast)	12/11/2008	59-2-5 ClearBallast-Jap-Final
Hybrid Ballast Water Treatment System using Seawater Electrolytic Process	Basic Approval of Active Substances used by the Hybrid Ballast Water Treatment System using Seawater Electrolytic Process	12/14/2006	56-2 Hybrid-Jap-Basic
Kuraray Ballast Water Management System	Application for Basic Approval of Kuraray Ballast Water Management System	3/25/2010	61-2-6 Kuraray-Jap-Basic
MES Ballast Water Management System (FineBallast MF)	Application for Basic Approval of the MES Ballast Water Management System (FineBallast MF)	3/17/2010	61-2-3 FineBallast-Jap-Basic
NK Ballast Water Treatment System	Request for re-evaluation of the proposal for the approval of Active Substances	8/18/2006	55-2-27 NK-ROK-ReSubmit
NK Ballast Water Treatment System	Basic Approval of Active Substances used by NK Ballast Water Treatment System	4/20/2006	55-2-3 NK-ROK-Basic
NK-O3 BlueBallast System	Application for Final Approval of the NK-O3 BlueBallast System (Ozone)	3/21/2008	58-2-3 NK-ROK-Final-1
NK-O3 BlueBallast System	Application for Final Approval of the NK-O3 BlueBallast System (Ozone)	12/8/2008	MEPC 59-2-3 NK-ROK-Final-2
OceanGuard™ Ballast Water Management System	Application for Basic Approval of the OceanGuard™ Ballast Water ManagementSystem	8/26/2009	60-2-8 OceanGuard-Nor-Basic
OceanGuard™ Ballast Water Management System	Application for Final Approval of the OceanGuard™ Ballast Water ManagementSystem	3/25/2010	61-2-7 OceanGuard-Nor-Final
OceanSaver® Ballast Water Management System	Application for Basic Approval of a ballast water management system using Active Substances	9/7/2007	57-2-6 OceanSaver-Nor-Basic

System	Title	Date	File name
OceanSaver® Ballast Water Management System	Application for Final Approval of the OceanSaver® Ballast Water Management System (OS BWMS)	3/19/2008	58-2-1 OceanSaver-Nor-Final
Peraclean® Ocean	Application for approval of an Active Substance for Ballast Water Management	4/15/2005	53-2-12 PeraClean Ger-Basic
Peraclean® Ocean	Application for approval of an Active Substance for Ballast Water Management. Corrigendum	5/27/2005	53-2-12-corr.1
Peraclean® Ocean & Sedna system	Application for Final Approval of a ballast water management system using Active Substances	9/7/2007	57-2-5 PeraClean(Sedna)-Ger-Final
Purimar™ Ballast Water Management System	Application for Basic Approval of Techwin Eco Co., Ltd. (TWECO) Ballast Water Management System (Purimar™)	3/9/2010	61-2 Purimar-ROK-Basic
Resource Ballast Technologies System (cavitation combined with Ozone and Sodium Hypochlorite treatment)	Basic Approval of Active Substances used by Resource Ballast Technologies System (Cavitation combined with Ozone and Sodium Hypochlorite treatment)	4/6/2007	56-2-3 Resource-SAfr-Basic
Resource Ballast Technologies System (cavitation combined with Ozone and Sodium Hypochlorite treatment)	Application for Final Approval of the Resource Ballast Technologies System (Cavitation combined with Ozone and Sodium Hypochlorite treatment)	12/19/2008	59-2-10 Resource-SAfr-Final
Siemens SiCURE	Application for Basic Approval of the Siemens SiCURE Ballast Water Management System	12/19/2008	MEPC 59-2-11 SiCure-Ger-Basic
Special Pipe Hybrid Ballast Water Management System combined with Ozone treatment version	Basic Approval of Active Substances used by Special Pipe Ballast Water Management System (combined with Ozone treatment)	4/12/2006	55-2 SpecialPipe-Jap-Basic
Special Pipe Hybrid Ballast Water Management System combined with Ozone treatment version	Application for Final Approval of the Special Pipe Hybrid Ballast Water Management System (combined with Ozone treatment)	12/4/2008	59-2-1 SpecialPipe-Jap-Final-1
Special Pipe Hybrid Ballast Water Management System combined with Ozone treatment version	Application for Final Approval of the Special Pipe Hybrid Ballast Water Management System combined with Ozone treatment version (SP-Hybrid BWMS Ozone version)	3/17/2010	61-2-2 SpecialPipe-Jap-Final-2

System	Title	Date	File name
Special Pipe Hybrid Ballast Water Management System combined with PERACLEAN ® Ocean (SPO-SYSTEM)	Application for Final Approval of the Special Pipe Hybrid Ballast Water Management System combined with PERACLEAN ® Ocean (SPO-SYSTEM)	3/29/2010	61-2-10 SpecialPipeSPO-Jap-Final
Sunrui ballast water management system	Application for Basic Approval of Sunrui ballast water management system	8/24/2009	60-2-3 Sunrui-China-Basic
BalClor ™ ballast water management system (formerly Sunrui BWMS)	Application for Final Approval of BalClor ™ ballast water management system	3/22/2010	61-2-4 Sunrui-China-Final
TG Ballastcleaner and TG Environmentalguard	Application for Basic Approval of the ballast water management system using "TG Ballastcleaner and TG Environmentalguard" as Active Substances (Toagosei Group)	12/26/2007	57-2-8-TG-Jap-Basic
TG Ballastcleaner and TG Environmentalguard	Application for Final Approval of the JFE Ballast Water Management System (JFE-BWMS) that makes use of "TG Ballastcleaner® and TG Environmentalguard®"	8/20/2009	60-2-2-TG-Jap-Final
Peraclean Ocean, ElectroClean	Report of the first meeting of the GESAMP-Ballast Water Working Group (GESMP-BWWG)	2/28/2006	54-2-12 GESAMP-Rpt 1
Special Pipe Ballast Water Management System (combined with Ozone treatment), NK Ballast Water Treatment System, EctoSys	Report of the second meeting of the GESAMP-Ballast Water Working Group (GESMP-BWWG)	7/7/2006	55-2-16 GESAMP-Rept 2
Hybrid Ballast Water Treatment System using Seawater Electrolytic Process, NKO3 BWTS, PureBallast, PureBallast	Report of the third meeting of the GESAMP-Ballast Water Working Group (GESMP-BWWG)	4/13/2007	56-2-2 GESAMP-Rpt 3
Electo Clean System, Clear ballast System, CleanBallast! System	Report of the fourth meeting of the GESAMP-Ballast Water Working Group (GESAMP-BWWG)	12/19/2007	57-2 GESAMP-Rpt-4
Resource Ballast Technologies System, GloEn Patrol, SEDNA using Percaclean Ocean, OceanSaver	Report of the fifth meeting of the GESAMP-Ballast Water Working Group (GESMP-BWWG)	1/25/2008	57-2-10 GESAMP-Rpt 5

System	Title	Date	File name
TG Ballastcleaner and TG Environmentalguard, Greenship's Ballast Water Management System, Electro-Clean System (ECS)	Report of the sixth meeting of the GESAMP-Ballast Water Working Group	7/14/2008	58-2-7_GESAMP-Rpt-6
OceanSaver, Ecochlor, NK-O3 BlueBallast System	Report of the seventh meeting of the GESAMP-Ballast Water Working Group	7/28/2008	58-2-8_GESAMP-Rpt-7
Special Pipe Hybrid Ballast Water Management System (with Ozone), CleanBallast, NK-O3 BlueBallast System, Blue Ocean Shield, EcoBallast	Report of the eighth meeting of the GESAMP-Ballast Water Working Group (GESMP-BWWG)	4/8/2009	59-2-16_GESAMP-Rpt_8
ClearBallast, Greenship Sedinox, AquaTriComb	Report of the ninth meeting of the GESAMP-Ballast Water Working Group (GESMP-BWWG)	5/5/2009	59-2-19_GESAMP-Rpt_9
GloEn-Patrol, Ecochlor, SiCURE, Resource Ballast Technologies System	Report of the tenth meeting of the GESAMP-Ballast Water Working Group (GESMP-BWWG)	10/30/2009	60-2-11_GESAMP-Rpt_10
ATLAS-DANMARK, TG Ballastcleaner and TG Environmentalguard, Sunrui Ballast Water Management System, DESMI Ocean Guard, Blue Ocean Guard (BOG)	Report of the eleventh meeting of the GESAMP-Ballast Water Working Group (GESMP-BWWG)	12/1/2009	60-2-12_GESAMP-Rpt_11
HiBallast, En-Ballast, OceanGuard, Severn Trent DeNora	Report of the twelfth meeting of the GESAMP-Ballast Water Working Group (GESMP-BWWG)	2/8/2010	60-2-16_GESAMP-Rpt_12
General	Guidelines on the Installation of Ballast Water Treatment Systems	Mar-10	0310_ClassNK-BWMS-Intsallation